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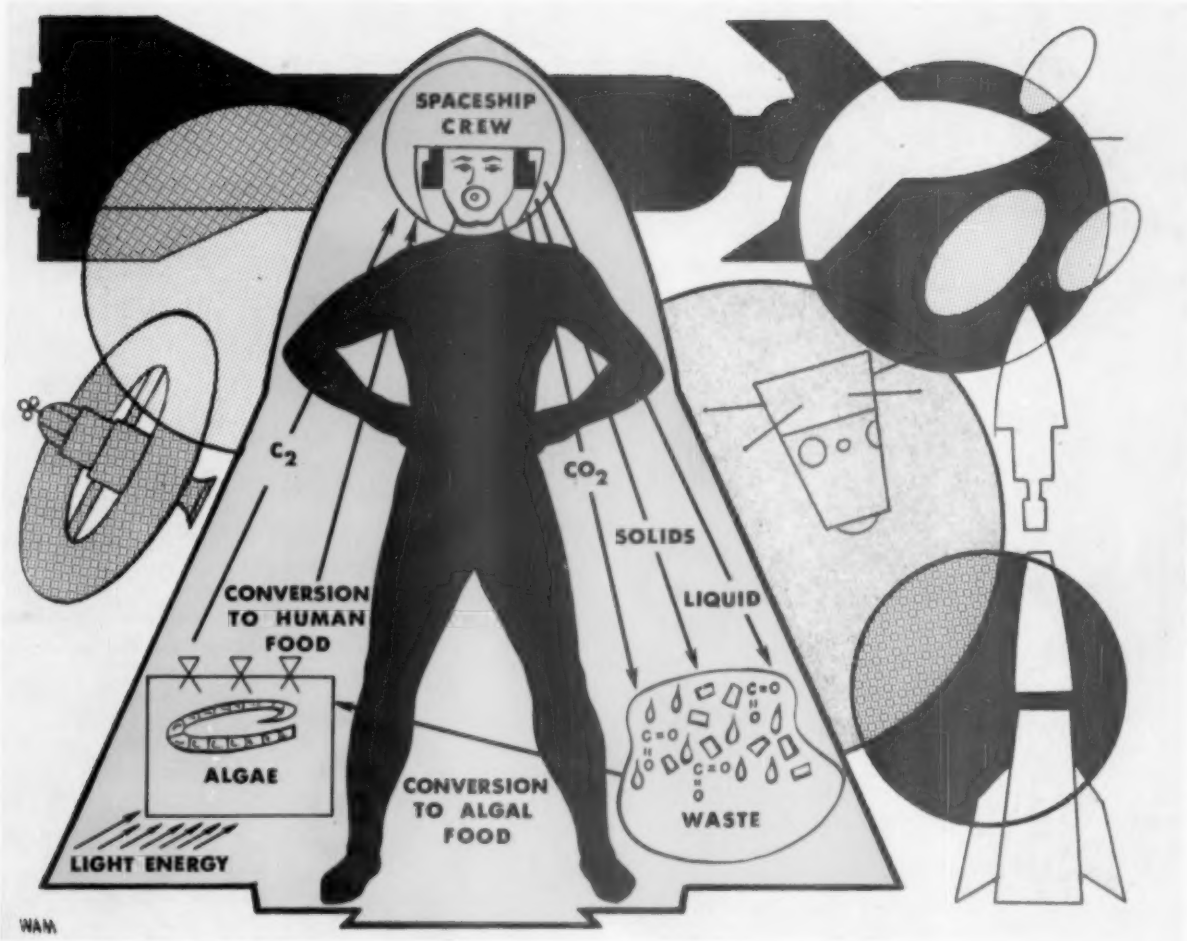
FT food technology



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IN THIS ISSUE—

THE TECHNICAL ARTICLES IN BRIEF

Space feeding *Nutrition, feeding systems, bibliography*

The seven articles that comprise this symposium concern: nutrition in space flight (baloon flight experience); limitations, both physical and environmental, imposed on the astronautical crew; feeding systems, specifically, closed biological systems; present capabilities for evaluating the problems of feeding men in space vehicles (Air Force studies). The bibliography (5 pp.) includes general materials on man in space, space medicine, space psychology, space engineering, space feeding systems, and Algae as a source of space food and oxygen. (See pages 429–463).

Evaluation *Hydration characteristics of rice*

Effect of freezing on the hydration characteristics of rice. Arnold S. Roseman.

Milled, undermilled, or brown rice when gelatinized, hydrated and frozen under the proper conditions became structurally altered. The dried treated rice (milled and undermilled) was white, uniformly spongy—when viewed with a low-power microscope—expanded or larger than raw rice, and hydrated quite readily, e.g., when immersed in water at room temperature for one minute, this rice absorbed 75% water (wet basis). Unmilled or brown rice had similar properties except that it was bran-colored and nonporous on the surface where the bran still remained intact. By variation of the conditions of freezing and dehydration, the hydration characteristics and appearance of the treated grains were controlled. Alteration of properties by this process could be inhibited by freezing in the presence of calcium nitrate, a swelling agent. Changes due to freezing were not manifested equally in different varieties of rice with marked variation of amylose content. A waxy rice with little, if any, amylose showed the least change. (See page 464).

Methodology *Detection of foreign compounds in capsicum spices*

Detection of foreign pungent compounds in oleoresin capsicum and ground capsicum, and chili spices. Paul H. Todd, Jr.

A simple and effective procedure for the detection of foreign pungent principles in oleoresin capsicum is reported. Procedure is based upon the selective oxidation of the unsaturated fatty acid present in capsaicin, and the resistance of saturated fatty acids and the amine portion of the molecule to oxidation under the conditions employed. It is effective in evaluating the presence of the vanillyl amide of pelargonic acid, shown to be the pungent principle in a commercial oleoresin. Use of this procedure will prevent misinterpretation of previously accepted methods for relating physical and chemical data to organoleptic pungency, as well as verify the authenticity of oleoresins. (See page 468).

Military feeding *Canadian Armed Services*

Prepared foods for the Canadian Armed Services. R. M. Ballantyne, J. Galbraith, J. H. Hulse, W. R. Smithies, and N. E. Stacey.

The need to simplify food preparation for troops at war is universally realized. Small ships of the Navy, isolated units of the Army and Air Force, particularly in Arctic Canada, present unique feeding problems, some of which can be solved by easy-to-use, stable prepared foods. A variety of "instant" meals, based on freeze-dried and air-dried meats, which need only the addition of hot water, and a number of prepared cereal mixes for bread, cakes, pastries and puddings will be described. (See page 470).

New instrument *For estimating internal vacuum*

Estimation of vacuum in unopened containers. E. G. Davis and A. G. L. Elliott.

An instrument for estimating internal vacuum in sealed containers is described. The instrument is easily constructed, more convenient to use than existing instruments of this general type. The performance of the instrument in service was assessed on a series of test packs

September Cover. The illustration on this month's cover, supplied by the Graphics and Photography Branch, Quartermaster Food and Container Institute for the Armed Forces, epitomizes the concept of feeding men in space. William A. Merrill was the artist.

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in 301 x 411 cans, and the results analysed statistically. Results showed that when used in conjunction with a calibration curve, internal vacuum of the cans could be estimated with a standard deviation of 1.3 in. Hg. Measurements on individual cans over a period of time showed that the changes in flip vacuum were very nearly proportional to the changes in internal vacuum over the range 0-24 in. Hg, and for practical purposes a linear relation may be used. The standard deviation in these estimations was 0.6 in. Hg. (See page 473).

Evaluation *Potato chip bars*

Development and evaluation of potato chip bars. R. H. Treadway, J. R. Wagner, C. F. Woodward, E. G. Heisler, and R. M. Hopkins

Potato chips crushed to ⅛ to ¼ inch on a side and compressed at 500 to 3,000 p.s.i. give self supporting bars in which the characteristic crunchy texture of the original chips is preserved. Oil loss is slight or nil if chips are fried in hydrogenated shortening and compressed in an automatic press under optimum conditions. Sensory evaluation of the chip bars after one year's storage resulted in scores high enough to indicate acceptability as a ration component for the armed forces. Canned bars stored at 40° and 70° F. for a year were still palatable; those stored at 100° F. were definitely lower in degree of acceptability. During the year's storage, the free fatty acid content of the bars remained substantially unchanged. Peroxide value of the air-pack product, however, increased appreciably during 100° F. storage. Oxygen content in the head space of the air-filled cans decreased decidedly during high temperature storage, indicating that a nitrogen pack should be used to prevent oxidative deterioration over a long keeping period. Evaluation by a consumer-type panel indicated that chip bars might also have possibilities as a civilian food product. With the less rigorous stability requirements of a civilian product, it should be feasible to fry the chips in a vegetable oil-shortening blend, which appears to make the flavor of the bar more attractive. (See page 479).

Objective, subjective measurement *Beef tenderness*

A comparison of an objective and subjective measurement of beef tenderness. A. H. Bockian, A. F. Anglemeier, and Lois A. Sather.

Tenderness of samples from the *longissimus dorsi* muscle of standing rib roasts was measured subjectively by a trained taste panel and compared with the energy required to grind samples from the same muscle in a grinder attachment on a home food mixer. Correlation coefficients of −.59 and −.60 were obtained between the objective and subjective tenderness measurements. The highest correlation coefficients were obtained when the meat was ground and tasted immediately after preparation. Duplicate samples showed about a 10% variation in the energy required. The grinder method, plotted and interpreted as by Miyada and Tappel *(8)*, suggests an inexpensive method for evaluating the tenderness of meat samples by which many samples can be processed in a short time. (See page 483).

Nutrition *Instant coffee powder nutrients*

Nutritional study of instant coffee powder. L. J. Teply.

Presence of an average of 0.33 mg. niacin per gram of instant coffee powder was confirmed by bioassay. Regular instant coffee powder contained from 0.22 to 0.53 mg. niacin per gram. Two samples of decaffeinated instant coffee powder contained 0.37 and 0.41 mg. niacin per g. Measurable, but low, levels of 8 other B vitamins and of sodium, calcium, iron and fluorine were found in instant coffee powder. (See page 485).

Packaging *Potential of aluminum containers*

Aluminum from the can maker's point of view. L. P. Gotsch, R. W. Pilcher, and R. H. Lueck.

Aluminum containers are available today only at a considerable price disadvantage with respect to their tin plate counterparts. Probability that future price reductions will break this pricing structure depends on the extent of reduction in aluminum prices. There is little question but that a satisfactory aluminum container can ultimately be engineered for many food products now packaged in tin plate cans. This engineering, through the necessity of increased gauges and extra enameling costs, will add to the initial economic disadvantage already imposed by the cost of the metal. The extent to which this situation can be relieved will depend upon the willingness of the packer to modify specific packing and handling

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operations so as to be suitable for the more easily damaged aluminum cans. Except for certain product areas where inside sulfide discoloration and rusting during shipment or storage are problems with tin plate, there appears to be no real performance advantage for aluminum which would justify a higher cost container. The value of a problematical consumer eye-appeal or other psychological advantages cannot be assessed on a technical basis. In view of the long range importance of the potential of aluminum containers, can makers will continue efforts toward developing the can making and can using know-how required to make aluminum containers commercially desired. They cannot do this alone. The future will depend in the final analysis on the cost of aluminum versus tin plate. (See page 487).

New device *For gas space in pulverant solids*

Determination of gas space in pulverant solids. Don Scott and Frank E. Hammer.

The gas space in packages of instant coffee on up to foods of much larger particle size can be determined by this device. It can be used on samples in sealed cans by attaching a can-puncturing tool, compound gage, and valve. (See page 492).

FUTURE MEETINGS FOR FOOD TECHNOLOGISTS

September 21–28	Eleventh World's Poultry Congress, Mexico City, Mexico
October 13–15	Association of Official Agricultural Chemists, Inc., Shoreham Hotel, Washington, D. C.
October 13–15	Packaging Institute's 20th Annual National Packaging Forum, Edgewater Beach Hotel, Chicago
October 22–24	Fifth National Vacuum Symposium, American Vacuum Society, Sir Francis Drake Hotel, San Francisco, California
December 26–31	American Association for the Advancement of Science, Washington, D. C.
March 4–6	Southeastern Conference on Better Foods, The Georgia Center for Continuing Education, University of Georgia, Athens, Georgia
1959	
May 17–21	**Nineteenth Annual Meeting of the Institute of Food Technologists, Bellevue-Stratford Hotel, Philadephia, Pennsylvania**
1960	
May 15–19	**Twentieth Annual Meeting of the Institute of Food Technologists, Civic Auditorium and Hotel Whitcomb, San Francisco, California**
1961	
May 7–11	**Twenty-first Annual Meeting of the Institute of Food Technologists, Hotel Statler, New York, New York**
1962	
June 17–20	**Twenty-second Annual Meeting of the Institute of Food Technologists, Americana Hotel, Bal Harbor, Miami Beach, Florida**

An open invitation is extended to readers of FOOD TECHNOLOGY to send in to the Editorial Office, 11406 South Bell Avenue, Chicago 43, Illinois notices of annual or national meetings of interest to food technologists.

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FT food technology

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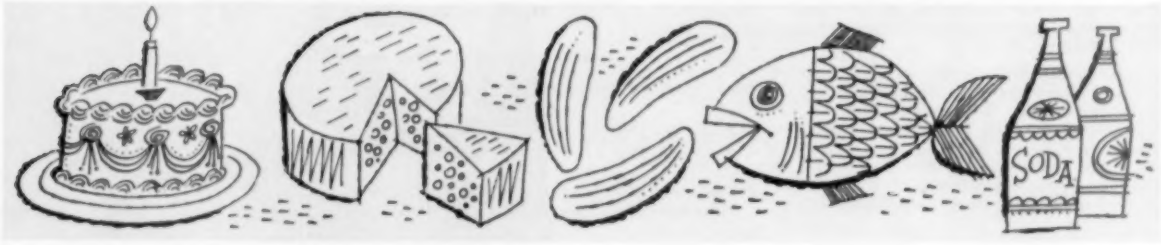

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WHAT TRAINING SHOULD A FOUR-YEAR FOOD TECHNOLOGY STUDENT RECEIVE?

Summary Report

ON THE EDUCATIONAL CONFERENCE
Institute of Food Technologists

Allerton House
Monticello, Illinois
May 21-23, 1958

Robert M. Schaffner,[a] Chairman

PURPOSE OF THE MEETING was to determine if it was possible to reach an agreement on what training a four-year student should receive to prepare himself for a career in the food industry.

Representatives

Forty-two people[b] attended the 3-day session; twenty-two coming from industry and twenty from institutions giving instruction in Food Technology. It was our desire to have a broad representation of the food industry present, but to still limit the number of attendants in order to have a working conference. Therefore, in order to have as wide a representation of industry as possible, all food companies that had ten or more Institute members were invited to participate. It was desired, however, to represent both large and small companies and in order to do this, all major trade and scientific associations were invited to send a representative so that they could speak for the small food manufacturer. All schools and universities giving instruction in Food Technology were invited and representatives from 15 universities attended.

Professional Level of Education

At the outset, the group agreed that Food Technology was a profession and that the basic disciplines to be discussed should be taught at the same level of training given to Chemists and Chemical Engineers. The "appreciation and terminal type" course was not favored.

Conference Procedure

Seven discussions on the basic disciplines were conducted by members of the Committee. The importance of each of the subjects was first discussed in general terms, and the possible contents of the different courses were outlined and discussed by both industrialists and educators. Following the discussion, industry members then voted on the matter of the course content and time required.

---

[a] Vice President, Libby, McNeill & Libby, Chicago, Illinois.

[b] *Participants*

J. C. Ayres, Iowa State College
G. W. Beach, Libby, McNeill & Libby
G. Borgstrom, Michigan State University
G. E. Brissey, Swift & Company
P. Buck, University of Wisconsin
C. O. Chichester, University of California
L. E. Clifcorn, American Can Company
G. S. Doolin, National Confectioners
W. B. Esselen, University of Massachusetts
C. N. Frey, Consultant
J. N. Friedman, Florasynth Laboratories
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J. M. Heinen, Continental Can Company
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W. Shannon, Oscar Mayer & Co.
C. Townsend, National Canners Association
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K. G. Weckel, University of Wisconsin
B. A. Wright, Armour & Company

In order to concentrate attention on the curriculum as a whole, Dr. R. T. Milner, University of Illinois, had a model constructed from wooden blocks. This was used throughout the meeting. Small wooden blocks represented the "semester hours" by which college courses are measured. For example, when the conference decided that 2 courses of 3 semester hours each should be included in the freshman year of the model curriculum, 3 blocks were taped together, labeled "English," and slipped on a retaining rod which represented the first semester of the first year. This was repeated for the second semester. A limit of 18 semester hours was clearly shown on each rod so that the conference was warned of the limiting load a student can carry in any one semester. The rods were mounted on 4 bases so that a base with 2 rods represented one college year.

This spring Dr. K. G. Weckel, of the University of Wisconsin, acting for the Committee, conducted a survey of all the schools giving food technology instruction. Purpose of the survey was to collect data on the types, content and credits of the courses being offered. Seventeen schools answered the inquiry and the data were assembled by disciplines. Mimeographed copies of this 25-page report were given to each conference participant and used as background data for each of the discussion periods.

SUMMARY OF DISCUSSION GROUP REPORTS

A Thorough Background in Chemistry . . .

The importance of a thorough background in chemistry was agreed upon. The fact that 54% of the present membership of the IFT have degrees in chemistry substantiates this point. In general it was agreed that the recommended courses in chemistry should be legitimate courses comparable to those taught in the schools of chemistry. Further, they should be the type of courses accepted as prerequisites for advance courses; the so-called terminal courses should be avoided.

In order that the balance of the curriculum could be fitted into the 4-year program, it was suggested that chemistry through physical chemistry be completed before the senior year. A 4-credit course titled Food Chemistry Analysis, taken during the senior year, would stress instrumentation, A.O.A.C. methods, as well as other applied chemistry techniques used in the food industry.

W. J. Shannon
Oscar Mayer & Co.,
Madison, Wisconsin

Need for a Dynamic Biochemistry Course . . .

Since foods are biological systems produced by plants and animals, it was agreed that a Food Technology curriculum should contain some training in biochemistry for the best orientation and understanding of food problems.

With regard to the content of the biochemistry course, it was strongly recommended that as much dynamic biochemistry as possible be included as contrasted to that dealing with structure and composition. Such training should result in a better understanding of enzymatic and chemical changes and the interactions of compounds taking place during food preparation, processing, storage, etc. Although this breadth of biochemistry may be difficult to include in one course, it may be possible by teaching more biochemical structure in organic chemistry. Ordinarily, an advanced biochemistry course should be necessary.

An understanding of the elements of nutrition was also considered to be mandatory training for the food technologist.

It was recommended by the industry representatives that six hours of study be allocated to biochemistry and nutrition, preferably to be given during the latter part of the third year of training. Whether nutrition would be offered separately or combined with biochemistry would be decided by each institution. The latter part of the third year was chosen since it was felt that the students would need this background for the food technology courses to follow in the fourth year.

L. E. Clifcorn
American Can Co.
Barrington, Illinois

A Foundation in Microbiology and Sanitation . . .

Prerequisites agreed on were biology (5 units) and organic chemistry (5 units). The biology course should be taken in the second semester of the Freshman year, and the organic chemistry in the first semester of the Sophomore year.

It was also agreed that there should be an introductory course in bacteriology of 5 units to be given in the second semester of the Sophomore year. Subject matter should include the study of bacteria, yeasts and molds with respect to morphology, growth characteristics and classification, the importance of these organisms in nature, aseptic techniques, pure culture study and counting procedures, media making, etc.

A second course, Food Bacteriology (5 units), should be required in the first semester of the Junior year. This should cover the important fermentations and food spoilage problems, together with public health bacteriology and bacteriology in its relation to sanitation. Other aspects of sanitation should be dealt with in the Food Technology courses.

C. Townsend
National Canners Ass'n
Berkeley, California

Basic Training in Mathematics and Physics . . .

It was agreed that training in mathematics was required in order to provide proper background for physical chemistry and unit operations. Because so many students in high school do not take advanced algebra it was thought that most schools should allow time for a course in college Algebra. The 3 semester hours of algebra should then be followed by 3 semester hours of analytical geometry at the end of the Freshman year. Mathematics courses for food technologists should, it was agreed, include both differential and integral calculus. These courses should be at least equivalent to those required in chemical engineering curriculum. These courses are necessary for a

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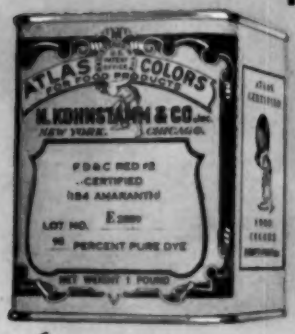

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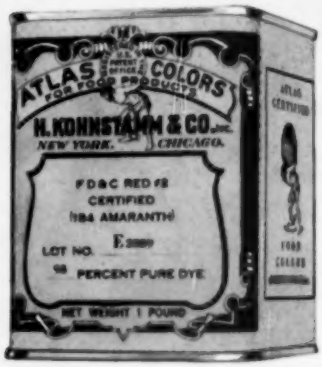

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student to take physical chemistry and unit operations. A total of 14 semester hours in mathematics was, therefore, put into the model curriculum.

Although there was some discussion as to the need of including a course in differential equations, the group, as a whole, thought that, though this might be desirable, it should not be a required course for food technology.

A course in statistics was also discussed. It was thought that this would be valuable but that it should be placed in the category of a 3-hour elective.

Training in physics is a necessity for a food technologist and the group agreed that at least 10 semester hours of physics be called for, keeping in mind that the level of the course should be the same as given to engineers or chemists.

R. B. Wakefield
Gerber Products Co.
Fremont, Michigan

Social Science, Humanities, Economics, Business Administration, English Are Not Forgotten . . .

In the selection of the various non-technical courses in social sciences, humanities, economics, English, etc., it was recognized that the particular requirements at a given college would play an important role. With this in mind, it was agreed that the model curriculum should provide:

- 6 semester hours in English;
- 3 semester hours in Speech and Technical writing;
- 3 semester hours in Economics;
- 12 semester hours in other social sciences and humanities

Courses in advanced economics, business administration, foreign languages, etc., could be considered as either part of the 12 hours allocated to other social sciences or as electives that may be included in the course.

How to use the library effectively should be part of the English course, but library techniques would also be practiced in some schools in the senior year (thesis in food technology courses).

It is generally recognized that technically-trained men are often deficient in the ability to express themselves orally or in writing. The fact that this deficiency has existed for decades is a serious indictment of the English and speech courses generally offered in colleges to technical students.

The crux to this problem is proper motivation of the student, since technical students in general have a deplorable lack of interest in non-technical courses, when they take them. What is taught him in English must not be remote from his daily living as a student. The English Department should teach theory, if necessary, then help technical departments in forcing the student to day-after-day practice of good English usage.

H. P. Milleville
Putman Publishing Co.
Food Processing
Chicago, Illinois

Needed: Engineering, the Application of Science To Unit Operations . . .

Engineering is the utilization of scientific knowledge and natural resources to design and construct useful things for mankind. It was pointed out that knowledge of practical application of basic scientific principles to fundamental operations and processes used in the food industry would be beneficial to the Food Technologist whether he became engaged in research, development, quality control, production, technical service or management.

It was agreed that the fourth year curriculum should include 10 hours of Unit Operations (lecture and laboratory) modeled after Chemical Engineering Unit Operations courses but adapted to the food industry. Prerequisites would be basic chemistry, physics, mathematics and bacteriology courses. A typical course description would be: Fundamental principles of food engineering operations. Heat transfer, fluid flow, evaporation, drying, extraction, distillation, filtration, mixing, etc.

It was felt that such a Unit Operations course along with Food Technology courses would enable the student to "tie together" his basic knowledge and acquire the engineering approach or "engineering state of mind" which emphasizes the practical utilization of scientific knowledge in application to food industry problems and is largely measured in dollar costs.

Additional elective courses suggested were: Thermodynamics, Stoichiometry, Applied Mechanics, Strength of Materials and Materials of Construction, Treatment of Data, and Instrumentation and Control.

J. M. Heinen, Jr.
Continental Can Company
Chicago, Illinois

Food Processing to Orient the Student for the Food Industry . . .

The food processing course is required to orient the student's training for the food industry. To achieve this goal it is suggested that in the Senior year a course be given with class room study, laboratory work, field trips, guest speakers, etc., which will integrate the student's entire four-year course. This might best be accomplished by investigation of food products and the developments associated with them. Such instruction would also offer an opportunity to introduce specific techniques related to each process.

For those institutions which deem it necessary, survey courses for freshmen are suggested to develop the student's interest in the field. A total of 12 credit units has been established for the accomplishment of the entire orientation.

H. M. Rich
Arthur D. Little, Inc.
Chicago, Illinois

MODEL CURRICULUM

In summary, the model curriculum, classified by various disciplines follows:

	Semester hours
Chemistry:	
Inorganic	5
Qualitative	5

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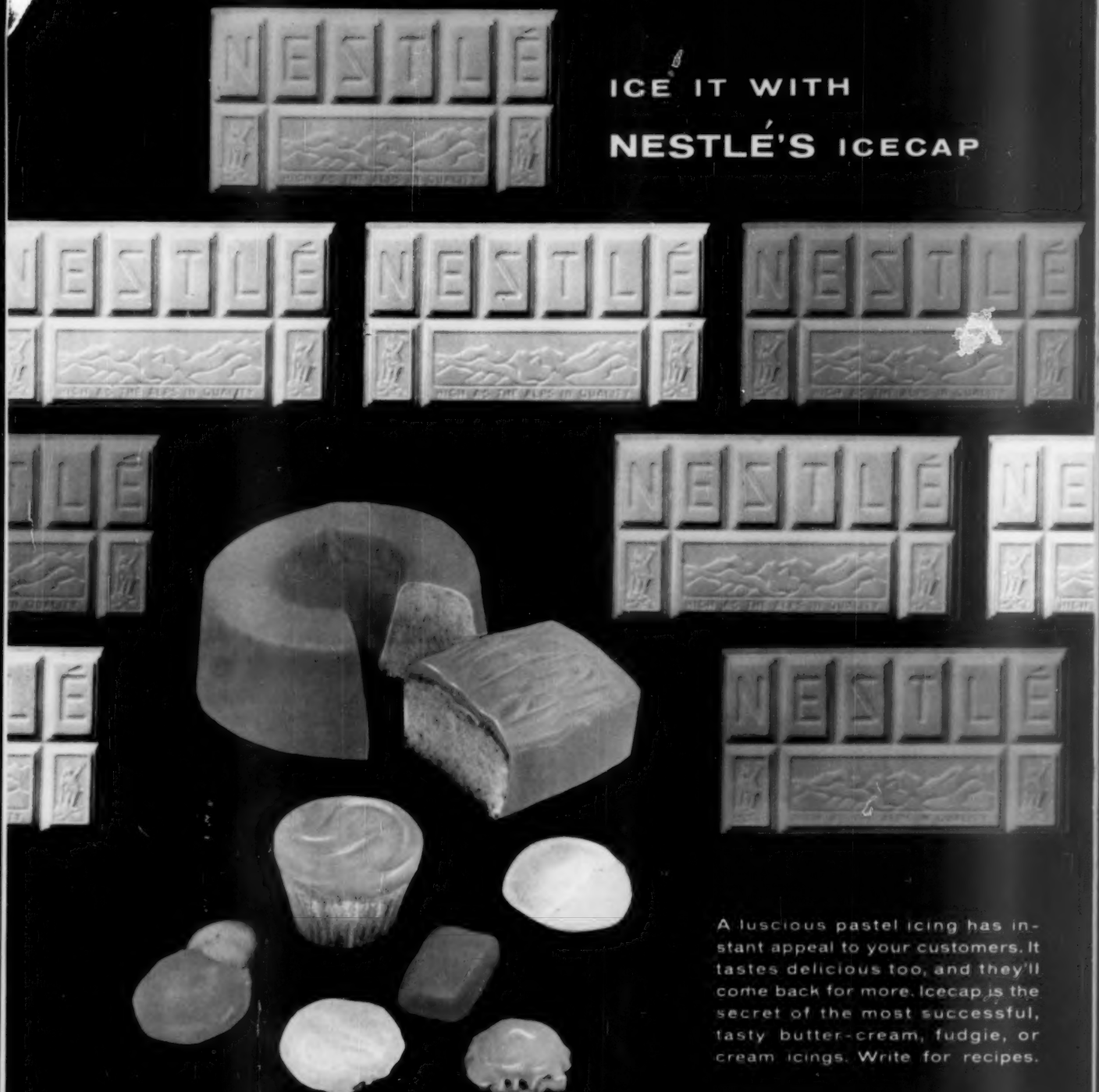

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*Trade Mark Reg

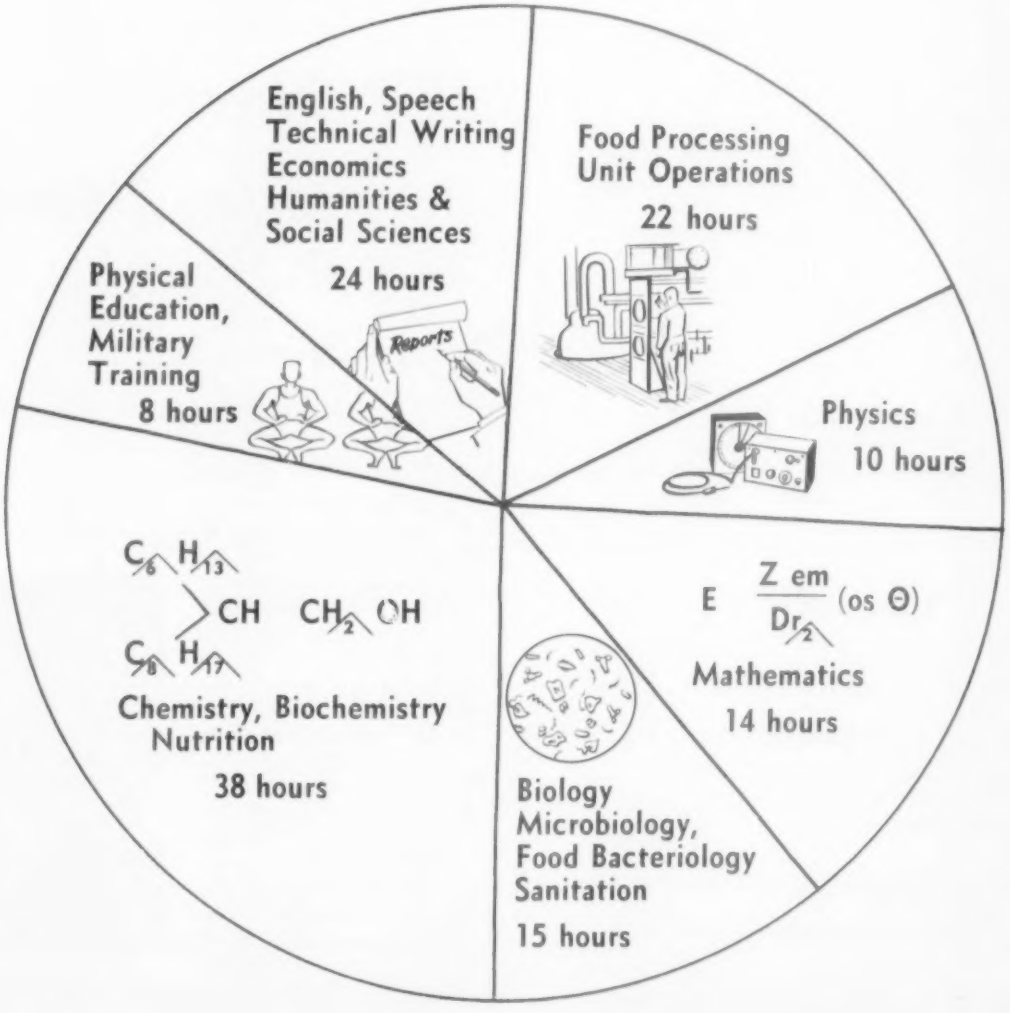
Quantitative	5
Organic	5
Physical Chemistry	8
Food Chemistry—Analysis	4
Biochemistry and Nutrition	6
Mathematics:	
Algebra	3
Analytical Geometry	3
Calculus	8
Biology	5
Microbiology	5
Food Bacteriology and Sanitation	5
Physics	10
Food Processing	12
Unit Operations	10
English	6
Speech and Technical Writing	3
Economics	3
Humanities and Social Science	12
Physical Education and Military Training	8
Total	131

It was noted that the model curriculum comes to 131 hours and most schools have available approximately 144 hours, so it would appear that there is additional room for electives.

The last morning of the conference was devoted to a discussion by the educators of their individual problems in connection with the model curriculum. The industrialists then unanimously voted to recommend to the Institute of Food Technologists that the model curriculum be approved. The educators unanimously agreed to accept the proposed curriculum as their goal.

PUBLIC RELATIONS PROGRAM

As a result of the same morning's discussion, the entire group of industrialists and educators recommended to the Institute of Food Technologists that an appropriate committee should promote the recruiting of Food Technology students by carrying out a public relations program on the profession of Food Tech-



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Speed, too. There's one of our sales offices as near as your phone. And the man you talk to has the home office as near as his phone, in case your question or problem is one he can't solve on the spot. We'll move fast.

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nology through the channels of high school teachers and teacher organizations.

The Committee also recommended that copies of the proposed curriculum and this report,[c] be distributed to all educational institutions offering courses in Food Technology. The Committee also suggests that the 1958–1959 Committee on Education prepare and send questionnaires to all food manufacturers, briefly outlining the model curriculum and inquiring how many food technologists having these qualifications they would hire, how many new technical people they ordinarily hire per year, and how much they might pay Food Technologists having the proposed educational background. The results of this survey would then be given to each of the educational institutions.

[c] At the Council meeting of the Institute of Food Technologists on May 25th, the recommendations resulting from this Conference were unanimously approved. This included approval of the proposed model curriculum and also the recommendation on the public relations program. To augment this, the Council allocated a sum of $500 to be placed in the budget to be used if needed for publication of these results in FOOD TECHNOLOGY and to defray expense of such reprints as are needed. Requests for reprints should be addressed to the Executive Secretary, Colonel Charles S. Lawrence, Institute of Food Technologists, 176 West Adams, Chicago 3, Illinois.

IFT News

Nineteenth Annual Meeting of IFT Shaping Up

Philadelphia is the Site: May 17-21, 1959 is the Date

"TECHNOLOGISTS, researchers, engineers, management officials, food journal editors and the food press generally can look forward to a stimulating program May 17 through May 21, 1959, in Philadelphia," reports Mr. Carl D. Pratt of the Atlas Powder Company, General Chairman of the Nineteenth Annual Meeting of the Institute of Food Technologists. Plans for the technical program are in full swing, according to the Co-Chairmen of this important phase of the meeting. The Co-Chairmen, and the officials to write to regarding program details, are Walter L. Obold, Ph.D., Head, Department of Bio-

Carl D. Pratt

Oil, vinegar, spice flavors—
and clear as a choice Rhine wine

You would know better than we whether there is any future in this idea.

The cruet contains 10% of water. It might have been vinegar. The rest is oil. Half of the oil is the usual triglyceride salad oil. The other half of the oil is distilled monoglyceride. It is equally wholesome food. The monoglyceride dissolves both the conventional salad oil and the water. This clear, uniform, stable solution can carry both oil-soluble and water-soluble condiments and flavor extracts.

It would be interesting to experiment with other ratios of triglyceride to monoglyceride. This is for food processors to do, not for us. Our business is making Myverol® Distilled Monoglycerides so pure they can give this effect. We shall be delighted to supply food processing firms with free samples for their experiments. ***Distillation Products Industries,*** Rochester 3, N. Y. Sales offices: New York, Chicago, and Memphis • W. M. Gillies, Inc., West Coast • Charles Albert Smith Limited, Montreal and Toronto.

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logical Sciences, Drexel Institute of Technology, Philadelphia, Pennsylvania, and John Sharf, Ph.D., Chief, Research and Development Center, Armstrong Cork Company, Lancaster, Pennsylvania.

W. L. Obold

John M. Sharf

Deadlines

Prospective contributors to the May 1959 meetings are requested to send in the titles of their papers to the Co-Chairmen (named above) or to the Session Chairmen, if listed in the tentative announcement below.

Deadline for titles is December 1, 1958.

Abstracts of all papers must be in the hands of the Session Chairman or Co-Chairmen Obold and Sharf by January 1, 1959.

The Sessions[a]

1. Cereal and Baked Products
2. General Research—H. H. Mottern, Ph.D. (Research and Development Division, Nat'l Dairy Products Corp., Glenview, Illinois)
3. Meat and Poultry—B. A. Wright (Research Division, Armour & Company, Chicago Illinois)
4. Radiation Preservation of Foods
5. Heat Processing
6. Fruit Products—C. H. Hills, Ph.D. (Head, Fruit Utilization Div., Eastern Regional Regional Research Laboratory, Philadelphia, Pennsylvania)
7. Fish—C. F. Evers (Technical Service Director, International Minerals and Chemical Corp., Chicago, Illinois)
8. Frozen Foods—J. G. Woodroof, Ph.D. (Chairman, Div. of Food Processing, University of Georgia, Athens, Ga.)
9. Automatic Process Control
10. Packaging and Pressurized Containers
11. Food Engineering
12. Food Additives—J. F. Mahoney, Ph.D. (Manager, Technical Service, Merck and Co., Rahway, N. J.)
13. Quality Control

[a] Additional session leaders were selected at the meeting of the National Program Committee at Drexel Institute of Technology on August 7, 1958, and will be announced later. Another possible session is "Antibiotics and Food Preservation," and if interest is sufficient, it will be added as session 14.

Awards

Call for Nominations

Nicholas Appert Award

The Nicholas Appert Medal and an honorarium of $1000, is awarded annually to a person for "preeminence in and contributions to the field of Food Technology."

Nominations for the Award may be made by any member of the Institute of Food Technologists. They must be in letter form giving a biographical sketch of the nominee and indicate the contributions that qualify him or her for the Award. Nominating letters shall be limited to two, single-spaced, typewritten sheets.

If you know someone who, in your opinion, is eligible for this Award, do not delay; send in your nomination today! Nominations must be submitted before November 1, 1958.

Send Nominations To:

Institute of Food Technologists
176 West Adams Street
Chicago 3, Illinois

Babcock-Hart Award

The Babcock-Hart Award, consists of $1,000, donated by The Nutrition Foundation and an engrossed plaque furnished by the Institute of Food Technologists. This Award is made annually to an individual "who has distinguished himself or herself by contributions to Food Technology which have resulted in improved public health through some aspect of nutrition or more nutritious food."

Nominations for the Award may be made by any member of the Institute. They must be in letter form giving a biographical sketch and listing the achievements of the individual recommended. Letters of nomination must be not more than two, single-spaced, typewritten sheets.

If you have someone in mind who, in your opinion, is eligible for this Award, do not delay; send in your nomination now! The deadline for nominations is December 1, 1958.

Send Nominations To:

Institute of Food Technologists
176 West Adams Street
Chicago 3, Illinois

Food Technology Industrial Achievement Award

The Institute of Food Technologists announces the establishment of a *Food Technology Industrial Achievement Award*. The Award will include the following:

(Continued on page 17 following Technical Section)

Feeding Men During Space Flights

Contributions to the Session on Space Feeding, R. G. Tischer, Chairman, Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 28, 1958.

By Way of Preface

PROBLEMS OF SPACE FEEDING have attained status as a result of the sudden, sensational events of the past several months—events that seem to guarantee the eventual practicability of space vehicles. Consequently, with space travel removed from the realm of the purely academic, it is none too early to begin discussing the difficulties of, and the potentialities for, supporting space crews engaged in interplanetary travel.

Scientists and engineers appear to be making great strides in developing concepts of the space ship. Launching platforms, propulsion devices, the instrument panel, even the cabin wherein the navigators will be plotting their course across the vast emptiness that separates us from our neighbors in the Universe —all of these problems are on the drawing boards. Unfortunately, it is not possible to pick up the drawing board and design a man for space travel. Instead, the scientists and the engineers must resort to creating for the man hurtling through space an environment approximating biologically the one he is used to, and then to hope that this little cabin in the sky will permit him and his hardy comrades to arrive at destination in good shape and to return to tell the story. Knowing, as we do, within what comparatively narrow limits of temperature man must live, what exacting nutritional needs he has, how delicately balanced must be the photosynthetic exchange system proposed as a method for sustaining life—bringing the space man back alive is a research project of enormous complexity.

Space feeding is a problem that embraces ecology, plant physiology including photosynthesis, biochemistry, nutrition, food technology and engineering, and many subsciences and technologies. Fortunately, there are storehouses of data in all of these fields. As will be evident in the papers that follow, past findings plus the results of experimentation under space-simulated or space-equivalent conditions are giving structure to a space-feeding system that can be taken seriously.

The authors of the several papers presented at the Space Feeding Session brought to bear upon the problems of feeding men aboard a space ship, a variety of viewpoints, each of them much influenced by the type of training and experience he has had. Thus, Lt. Colonel David G. Simons, an Air Force Medical Corps Officer whose Manhigh II balloon flight carried him to the border of free space, considers physiological problems from the point of view of both test subject and observer, a novel combination. Prognosticating a possible room-size ecological system was the province of Dr. James G. Gaume, physician for the Denver Division of the Martin Company, Dr. Robert G. Tischer, Dr. Maxwell Brockmann, Mr. Albert S. Henick, Dr. George Kurtz, all of them U. S. Army Quartermaster Food and Container Institute scientists, and Lt. Colonel Albert A. Taylor, USAF (VC) long identified with Air Force research and development. Components and operating requirements, which represent both the potentials for success and the pitfalls of possible failure, are discussed.

Two British scientists, Mr. S. W. F. Hanson and his colleague Mr. H. P. Hinton, while by no means taking a negative view, infer with refreshing candor that a strong stomach will be one criterion for selecting a candidate for space travel. They suspect that the first man-made bower that houses the ecological system will have its aesthetic limitations and so, too, the spaceman's algae menu.

Miss Beatrice Finkelstein, Aero Medical Laboratory, USAF, extrapolates, as it were, from (1) data on long-range high altitude missions and (2) from data on several current Air Force nutrition research studies under conditions simulating some of those of space travel, in order to underscore the critical problems ahead with regard to preparation equipment, nutrition, and the acceptability of foods for space travelers. A selected bibliography by Drs. Hodgson and Tischer amply supports the claim that there are storehouses of data available for those who may wish to see for themselves what the prospects are for feeding the venturesome explorers who will, most literally, be embarking for parts unknown.

For those of us who are content with being firmly anchored to Earth and not quite willing, as yet, to believe in space ships, it is nevertheless not possible to escape the fact that we have entered the Era of Space. It is a foregone conclusion that the years ahead will be marked by an increasingly intensified interest in limitless space and its undiscovered worlds.

History tells us that when human society is seized by these profound, headlong enthusiasms — other phases of its culture suffer neglect. If this neglect occurs in what we must accept as a culture trait, *war*, few will lament the loss. If it means a diminishing

concern with the humanities, that is not so pleasant a prospect. It would be a pity, also, if in the process of working up edible dishes for the space men, we should fall victim to a side effect and lose our appetite for and interest in our delectable traditional foods.

For the present and the foreseeable future, however, our traditional foods are quite safe. The problem of space feeding is far from solved. And, until the food problem *is* solved, the Earthlings are not very likely to panic the Martians by disembarking, some evening at the witching hour, on a Martian plain.

M. S. P.

Some Observations on the Problems of Space Feeding*

(Manuscript received May 17, 1958)

S. W. F. Hanson
London, England

IF A COMMENTARY on such a subject, by definition infinite in scope, is to be made within the short space allotted, the first requirement is to reduce the enormous mass of imaginative, opinionated, and conflicting suggestions in the literature to a few simple and reasonable circumstances.

Before preparing the luncheon basket, one wishes to know how long the travellers will be out—and what the weather will be like.

Let us first deal with the latter point, the environment of the space traveller. Although attempts have been made, and occasionally with success, to throw small pieces of hardware into elliptical orbits around the earth by means of multi-stage rockets fired from its surface, the weight of informed opinion seems to indicate that a manned space vehicle would require a relatively large manned satellite space-station as its starting point. I shall not deal with the problems of feeding on this satellite depot since I think they are clearly less limiting than those on space ships, and more appropriate to a discussion of the logistics of transporting fuel, materials, personnel and waste products to and from such depots. There might even be room in this case for such luxuries as frozen foods, as was hopefully claimed by the frozen food industry in a recent journal article.

"I REFUSE TO CONSIDER THE FEEDING OF OUR TRAVELLER UNLESS . . ."

In searching for information on living conditions in the space ship itself one is faced with a multitude of views. It would appear that the traveller is likely to be faced with many hazards, among which we can count tremendous accelerations, collision with meteorites large and small, solar heat and other radiations, cosmic radiation, suffocation, starvation and thirst; not to mention psychological stresses. I refuse to consider the feeding of our traveller unless his continued existence is otherwise assured, by the provision of oxygen and the removal of carbon dioxide and water vapour from the air, by adequate air pressure, by temperature control, by protection from radiation and such arrangements as seem possible to deal with all but catastrophic puncture.

On the subject of acceleration, it has turned out that this need not be the terrifying factor of earlier writings; but the intriguing problem of artificial gravitation is not easy to resolve. There are those who claim that weightlessness would be no problem, but since the only available evidence comes from a few experiences for periods of seconds, in special manoeuvres by high-speed aircraft, during which some of the subjects felt comfortable and some felt sick, it would be improper to jump to conclusions.

It seems true that the bodily functions of eating, drinking and excretion are controlled by muscles and largely independent of gravitation; but this is of little assistance to gracious living if, for example, your drink will not remain in its glass—to mention but one possible embarrassment. On the whole I feel sympathetic to those designers who have imagined the living-quarters, at least, of their vehicles to revolve to produce an artificial gravity. This would, of course, increase towards the walls, upon which the crews would walk, and it would produce the odd effect that if they ate in a standing or sitting position their food would increase in weight as it went down. One can picture them, therefore, reclining on couches on the wall, to eat in sybaritic posture in an air-conditioned atmosphere.

You will see that I reject the oxygen-mask, pressure-suit, ejection-seat syndrome, and all the Air

* Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 28, 1958, by Mr. H. P. Hinton.

Force in-flight feeding system that goes with it, if only because of the time factors which I shall now present.

NAVIGATION IN SPACE—A PROBLEM IN THREE ORBITS

Since both the starting points and the objectives of space journeys will always be moving at great speeds on different orbits, and the space machine will be moving at great speed on a third orbit, the "great circle" routes of air-liners, which look so puzzling on a map, will be as the crow's flight compared with the three-dimensional problems of navigation in space. Calculations will have to be made to depart at such a time and in such a direction as to intersect the path of the objective at as short a distance as possible. The return might take very much longer as the base has been moving away during the journey; unless one waited for a favourable opposition again, in which case the time of waiting might be long. Altogether then a round trip will necessarily take longer than twice the outward-bound time.

For our purposes, two kinds of journey may be considered. Firstly, a voyage to the moon will take about 5 days each way (since in this case its distance from the earth remains constant) but the expenditure of so much resource and physical energy could hardly be justified without a lunar exploration lasting some days. Let us then consider that a visit to the moon lasts a couple of weeks.

The ultimate goal of space flight will, however, undoubtedly be an expedition to one of the nearer planets. And these are not so near. At their closest Venus is about 26 million, and Mars about 35 million, miles away; so that the shortest interplanetary journeys would take over three months for the outward journey and at least 15 months for the round trip. The excursion to Mars is commonly reckoned as a three year affair.

THE LUNAR EXCURSION

These considerations pose two different feeding problems, and we shall consider the conditions of the lunar excursion first. It has been argued at some length that for periods of a week or two the most economical method of atmosphere regeneration in a space-ship would be to absorb carbon dioxide chemically (and we shall not enter into the controversy as between the lighter lithium oxide or the more efficient calcium oxide, or between regenerative and non-regenerative systems), and to provide oxygen from a supply of liquid oxygen. Water vapour seems best removed from the air by refrigeration equipment as in everyday air-conditioning, and this gives an opportunity to control the air temperature at the same time.

In this closed system there is a continuous accumulation of water derived from the traveller's metabolism, and exhaled, perspired and excreted by him; and therefore the situation is quite ideal for the use of dehydrated foods. Start with a little water to rehydrate and accompany the first meals, and not only can that water be recovered, but also the additional water produced by oxidation of the food itself.

It is hardly necessary to recount the advantages of dehydrated foods to an audience of food technologists, but since they are extremely light (80% of meat and fish and 90% of vegetables is water, which is removed by the process) and not perishable (thereby needing no refrigeration), they need only ease of preparation, palatability and nutrient quality to justify their claim to solution of this problem. Recent advances, initiated by military demands, have brought these requirements to realisation. Freeze-dried foods (brought within commercial feasibility by British developments in "accelerated freeze drying") are of prime nutrient quality, attractive in appearance and flavour, and can be made up into a wide variety of meals. Moreover they are reconstituted almost immediately on the addition of water, and can even be pre-cooked so that the mere addition of hot water, or a short period of heating, is sufficient to prepare a meal. A reasonable menu can be provided by 2¼ lb. of such food per man per day.

INTERPLANETARY TRAVEL

Now we turn to the more formidable proposition of interplanetary journeys lasting for several years. There is a curious unanimity on this subject by the many authors who have referred to it and who have been intrigued by the possibilities of a microcosmic biological cycle. Given solar energy—and it would be hard to avoid that—the conditions seem to call for an attempt at setting up a balance so that the photosynthesis of plants would consume carbon dioxide and water, at the same time producing oxygen and plant tissues which could be consumed by humans. Nitrogen, sulphur, and mineral cycles would also have to be organised, but academically the suggestion is attractive.

It is when they are closely studied that the proposals make one grateful that they refer to a possibility which is still a good way off. For one thing they largely plump for the intensive production of *Chlorella* as the solution, many of them dismissing the problem thus, but others going into details of weight, space and productivity with amazing naivety. For another thing they generally assume that one can live on *Chlorella*.

CHLORELLA?

Without going into argumentative details about *Chlorella* culture, let me say that apparently quite unjustifiable calculations have been made to fit the process into the space-ship requirements from the results of an extremely limited number of pilot plant experiments carried out under quite different conditions. One point only which springs to mind is the suggestion, in one detailed paper, that water could be recovered from urine by an ion exchange apparatus. If, by any chance, this had not 100% efficiency throughout its perpetual cycling, then the water produced would become more and more saline and it

would therefore seem profitable to investigate the characteristics of organisms more tolerant to brackish water than is *Chlorella*. Similarly the treatment of faeces is usually dismissed by the suggestion that they be incinerated and the ash used as fertiliser for the plants, without any evidence being presented that it is indeed assimilated by *Chlorella*. Finally I would suggest that to keep the system going indefinitely without contamination or infection by plant or animal pathogens, and without reduction in output, presupposes a biological control rarely found elsewhere.

I have not even mentioned the psychological revulsion such a system must produce, for it would seem little better than drinking one's own bathwater. Indeed in such a microcosm it would appear more than likely that one might be brought, of necessity, into nauseating intimacy with the process, universal in the macrocosm of Earth, of second- or third-hand cannibalism.

Nevertheless none of these considerations are the basis of my rejection of *Chlorella* culture as the solution to the interplanetary feeding problem. Even if research and development produced a compact and operational piece of equipment to grow the organism, the fact would remain that *Chlorella* is not *food*, despite its content of nutriments. Humans cannot be expected to live on an interminable diet of green paste and, indeed, there is no evidence that they are able to do so. This has been the obstacle to many bright ideas for coping with the world's problems of nutrition (as witness the frustrating experiences on *Torula utilis*, fish flour and leaf proteins), and until it is solved no progress will be made along these lines.

THE PHASE BEYOND—GROWING FOOD ON THE MOON OR PLANETS

In saying that the space-feeding problem for lunar voyages is solved, and for interplanetary voyages is not, I have commented on the travelling phase of the subject I was given, but before I conclude I would like to air a few ideas about the next phase beyond—that of producing food on the moon or planets. It seems that on the moon one would have to provide an artificial atmosphere and a closed gas and water-vapour system, which might be possible by an application of our knowledge of hydroponics. There is a suggestion that below the moon's surface there are enormous caverns with relatively small openings. These would offer some protection from radiation and meteorite bombardment as well as insulation from the violent extremes of heat and cold.

Of the planets little is known, but it is easy to imagine possible hazards. For one thing you will recall the defeat of the Martian invaders in Wells' "War of the Worlds," by terrestrial infections against which they had no immunity. If organisation on the planets has at least reached that vague transition stage between large molecules and living matter inhabited by viruses, for example, there may be infections catastrophic to man or his plant food. Moreover, anaerobic forms of life might exist which would "detoxicate" all forms of life producing oxygen, which would be as lethal to them as chlorine is to us.

Finally, I should not like to leave this depressing tale without recounting Haldane's observation that molecules of living substance have the same kind of asymmetry, and yet their mirror images would probably work just as well in a system which by chance could have developed along analogous evolutionary lines. Such compounds could conceivably constitute living material on Mars or Venus, in which case we would find food on these planets without nutritive content (except for the symmetrical fats) and, indeed, by "steric hindrance" they might block the normal processes of metabolism at a vital stage, and be fatal.

One reaches the conclusion that even when technique and foresight permit space travellers both to leave Earth and to return, it would be well to arm them with the fullest possible range of antibiotics (and their optical isomers) and quarantine them, lest they return only to devastate the food supplies of mankind.

Nutrition in Space Operations *

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(Manuscript received May 17, 1958)

MANNED SPACE OPERATIONS of the future will be quite varied in nature and scope. Before we can discuss adequately the problems of nutrition in space operations, we must first classify the present and future stages of human flight. Figure 1 classifies these stages with regard to the vehicle, the environment, speed, gravitational condition, and flight dynamics.

Food logistics for each of these categories of flight will be quite different. For example, in the routine atmospheric flight of today, (Class I above) the in-flight food packs contain foods similar to those in our daily menus, and are prepared in the usual manner prior to take-off of the aircraft. This situation is likely to prevail so long as we fly in conventional aircraft which depend upon atmospheric oxygen as the oxidizer for its fuel.

In Class II—Space Equivalent Flight—food logistics are and will be quite similar. Flights in the space-equivalent region of 10 to 120 miles will be of short duration and may not require in-flight feeding. These flights include those of experimental high-altitude jet and rocket aircraft and ballistic rocket flight which will not attain orbital altitudes or velocities. One notable exception to this would be satelloid flight, defined as powered circumterrestrial flight of a vehicle in the upper space-equivalent portion of the atmosphere. Food problems here would be essentially the same as in Class III or satellite flight.

This discussion, then, is concerned only with Classes III and IV of the chart in Figure 1. In space operations in these categories food logistics will become extremely important.

First, let us establish criteria by which we can select the types of foods and solve the food problems for each kind of space operation. These criteria may be listed as follows in the order of priority:

1. Duration of flight operation.
2. Payload.
3. Methods of preservation and storage.
4. Methods of preparation.
5. Ease of eating.
6. Palatability.
7. Disposal of remnants or waste.

FOOD IN TERMS OF DURATION OF FLIGHT AND PAYLOAD

At this time, we can distinguish only arbitrarily between short term and long term flight. The point of separation will be determined by the feasibility of a storage system for necessities such as food, water, oxygen, and carbon dioxide absorbant, as compared to a system which re-utilizes waste materials in recycling and reproducing these items. On this basis, one might suggest that short term flight would be in the order of 2 to 4 weeks in duration.

Included in this category would be earth satellite operations not exceeding this period of time, circumlunar flight and return, and lunar flight with landing and a stay of perhaps one week's duration, before returning to earth. Thus, lunar trips of these types can be classed with the short term space operations.

Long term operations would include the permanent earth satellite station, the permanent lunar station, and interplanetary operations within our own solar system. Problems associated with flight beyond our solar system are not a part of this discussion.

* Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 28, 1958.

	I	II	III	IV
Classification Of Flight	**Atmospheric Flight**	**Space-Equivalent Flight**	**Circumplanetary Space Flight**	**Interplanetary Space Travel**
Status Of Vehicle	**Airplane**	**Airplane Projectile**	**Satellite**	**Space Ship**
Characteristics				
Environment	Atmospheric	Partial Space Equivalent (10 to 120 Miles)	Total Space Equivalent (120+ Miles) Free Space (6000+ Miles)	Free Space (600+ Miles)
Speed	Subsonic Supersonic	Supersonic Hypersonic (10+ Mach)	Orbital Velocity (17,500 MPH)	Escape Velocity (25,000 MPH)
Gravitational Condition	Normal	Subgravity Zerogravity	Zerogravity	Zerogravity
Dynamics	Aerodynamics	Aerothermodynamics Aerochemodynamics	Astrodynamics (120+ Miles) Altitude	Astrodynamics

After Strughold (11)

Figure 1. Present and future stages of human flight.

The weight of food used in all operations must be kept as low as possible.

PRESERVATION AND PREPARATION

In my opinion, for early space operations the best type of food which could be used would be the dehydrated foods which would be compressed into bite-size wafers or tablets. There are several reasons for this, and these reasons would seemingly answer all of the criteria given.

First of all, various foods could be compressed together bound by a digestible filler material. This technic would tend to diminish any strong taste which a single dehydrated food might have. Different flavorings could be added to provide pleasant and varied menus. Vitamins and minerals could be chewed and swallowed with water or other liquids. Milk could be treated in the same manner, its reconstitution occurring in the mouth and the stomach. The shape of the tablet or wafer should be tailored to fit the space designed for food storage.

It seems that such a method would make easier the preservation of foodstuffs whether this would be accomplished by chemical, electronic, or by irradiation methods.

In early space operations, to obviate the necessity of preparing food in flight would be most desirable. The various problems associated with zero-gravity might make food preparation very difficult. Let me explain.

Eating and drinking experiments have been performed during zero-gravity flights and in the F-94C at the USAF School of Aviation Medicine at Randolph Air Force Base, Texas and at the Aero Medical Field Laboratory at Holloman Air Force Base, New Mexico. These experiments have shown that it is relatively easy to drink from a plastic squeeze bottle with one small opening, whereas drinking from an open container is very inefficent, wasteful of water, and potentially dangerous. The swallowing of food is likewise not difficult if it is well masticated and sufficiently moistened.

Other experiments on the behavior of fluids and gases during zero-gravity indicate the difficulties one might encounter in trying to prepare meals in the weightless state.

It would be excellent if the first space crews were not required to concern themselves with meal preparation, but could simply put into their mouths a tablet of well-balanced food, containing all the essentials, chew, mix with water, and swallow.

The first men in space will have so much to think about and to do that, considering the difficulties which might attend food preparation, it would be far better if the concentrated food tablet were available to them.

You will notice that palatability is near the end of the list of criteria. It is one of the least important from the standpoint of necessity. Psychologically of course, it should be higher on the list, particularly during flights of a week or more.

DISPOSAL

The last of the criteria—disposal of remnants—would be completely eliminated by use of the food concentrate. In addition, because of the low residue of such a diet, the amount of human waste would also be diminished, thereby facilitating handling of such materials in zero-gravity.

An alternate type of food could be thick liquid or paste foods in a tube, from which the food could be squeezed directly into the mouth.

I realize that there are many difficulties associated with the concentration and preservation of various foods, but I am sure that these difficulties are also not insurmountable.

REGENERATION WITHIN A SEALED ECOLOGY

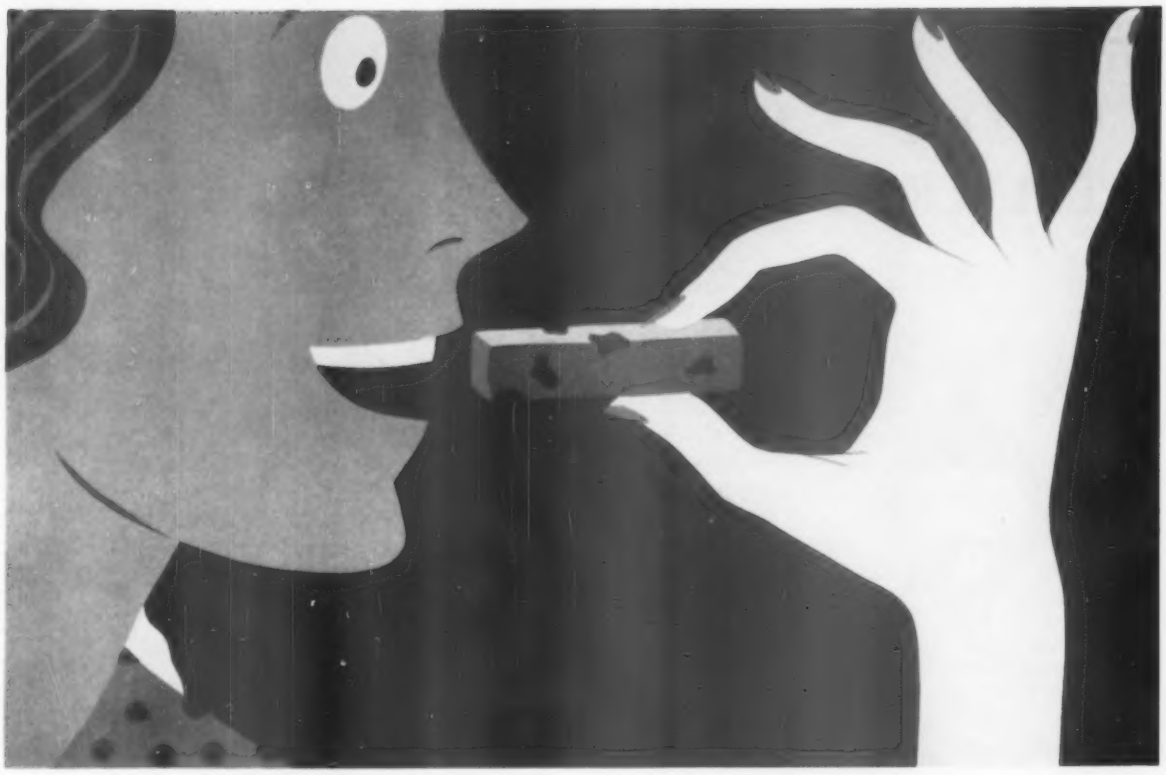
Long-term space operations have been categorized as the permanent satellite station, the lunar station, and interplanetary operations.

In all these operations, it will be necessary to utilize a recycling, regenerative system to produce within the sealed ecology all necessities for life, and to reutilize all waste materials in doing so. The most feasible method of accomplishing these objectives at present seems to be the use of a natural photosynthetic exchange system, utilizing one or more of the common algae.

Under proper conditions, a given amount of algae can be made to produce enough oxygen to support one man, and to absorb the carbon dioxide given off by the man. Dr. Jack Myers at the University of Texas, has found that five pounds of the green alga *Chlorella pyrenoidosa* can effect the balance in gas exchange with one man. A lesser amount of a blue-green alga, *Anacystis nidulans*, might do the same.

Tamiya and Morimura, of Japan, and others, have conducted feeding experiments and chemical analyses of the alga *Chlorella*, and have found this alga is almost a complete food, offering the essential amino acids (except those containing sulfur), lipids, carbohydrates, and most of the vitamins and minerals required by humans. The chemical composition can be altered to some extent by controlling the variables affecting the growth and composition. These include light intensity, method of illumination and wave length used, composition of nutrient solution, density and thickness of suspension, turbulence, rate of aeration and carbon dioxide concentration, pH of suspension, and frequency and rate of harvesting. One unknown factor at present is the effect of zero-gravity on the growth of algae. It may be necessary to provide an artificial gravity of up to one g for best results. It is even possible that more than one g would increase the efficiency of the algae! The gravity factor must be assessed.

A simple means of separating the algal cells from the nutrient solution should be developed. To this end, it may be possible to develop a digestible and nutritious filter made of food materials required to supplement the algae. The filter could be inserted at some point into the algal exchange system to filter the cells from the suspension. This would be removed



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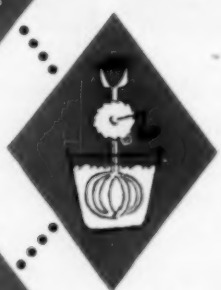

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after an optimum period of time. The filter wafer which holds the algae could then be suitably processed, depending upon the method required, for human consumption. A filtration method of this type could also be the means of continuously harvesting the algae, and of maintaining the density of the algal suspension at the point of optimum growth or oxygen production, or both. Of course, a system for manufacturing the filters must be provided on board the space ship. This system must also be very compact and of low weight. The filter residue after digestion with the algae could then be processed with other waste in the closed system to provide nutrients for the algae. Thus, another step in developing a balanced closed system could be accomplished.

Gotaas and Oswald of the University of California have utilized sewage wastes to grow algae. Wastes of this kind contain all elements necessary to life in low energy form. In reality such materials are not wastes but necessities. Algae grown on sewage in Southern California yield as high as thirty tons to the acre, whereas the field crops in the area produce only 1.5 tons per acre. These algae crops have been used successfully as livestock feeds.

Dr. Robert Gafford at the USAF School of Aviation Medicine has maintained mice and the alga *Anacystis nidulans* together in a closed system for a period of 12 days. The oxygen content of the system increased to 38% during that time. That particular alga also produced carbon monoxide but not in sufficient amounts to permanently harm the mice.

The trend of future research in this area will be

1) toward the screening of many algae for their suitability in these exchange systems;
2) investigations of the physiology of these algae;
3) the utilization of wastes of the animals in closed systems to feed the algae;
4) the harvesting of the excess algae to feed the animals in the system.

When these objectives have been accomplished, man will be incorporated into a closed system in place of or with the animals.

OUR MOTHER SPACE SHIP—THE EARTH

Perhaps all this may sound difficult or even unattractive to some of you, but stop to consider for a moment. We are even now on a giant space ship—the earth. It is moving in its own orbit as a satellite of the sun, at a velocity of 18.6 miles per second—3.5 times the velocity of an earth satellite. The earth is also a closed ecological system, sealed off from the unfriendly environment of space by its gravitational force. This force holds to the earth all the substances critical to life. These critical materials are constantly being recycled, from waste to product and back again.

In our feeble attempt to leave the protection of our mother space ship and venture into space, we must create in miniature, a world of our own which will duplicate all the essential functions which the earth performs for us. In this age of sub-miniaturization, it does not seem an impossible task to produce such a system. Our knowledge will increase and the job shall be done.

The challenge of the algae offers several new areas for research. Some of these are:

1) The screening of many different algae for suitability as food as well as for oxygen production and waste re-utilization.
2) Treatment of algae to improve their acceptability and "customer appeal."
3) Use of algae as ingredients in food concentrate tables or wafters.
4) Determination of the best combination of other ingredients to use with algae, to supplement the nutritional value of the algae.

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Nutrition in Space Flight

Balloon Flight Experience

(Manuscript received May 3, 1958)

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THE AXIOM, the way to learn how to do a thing is to do it, applies to the problems of manned space flight as much as it does to any other previously tried endeavor.

At this time, no Government agency has a firm commitment to execute a space program. When it comes, very specific problems will have to be faced. In the same way that link trainers have been found invaluable for training pilots and maintaining their proficiency for instrument flight conditions, the use of high altitude balloons can be equally useful for studying the problems of manned space flight under space equivalent conditions.

In considering the problems of manned space flight one point is crucial: the function of the man himself. The one thing a man in space can do that lower animals and black boxes cannot do is to use his creative imagination. When man is alert and thinking he can see new problems and anticipate methods of studying and solving them.

A balloon flight at 100,000 feet achieves space equivalent conditions in all but one major area. The temperature control problem is essentially that of orbital altitude at 100 miles or higher. At 100,000 feet less than 1% of the atmosphere remains. This vacuum does not permit heat to flow by convection and air conduction, but only by radiation as in free space.

The feeling of isolation in a lonely capsule (Figure 1) 19 miles above the earth is doubtless quite comparable to what one would expect in an orbiting satellite. Nutrition, also, is basically similar. The one thing that we know is significantly different in balloon flights as compared to orbital flight is weightlessness. The exit and reentry acceleration patterns influence structural design, but may not be a major factor in a man's reactions while orbiting.

WEIGHTLESSNESS

What will weightlessness mean nutritionally in space? A number of interesting phenomena associated with eating have been observed by Dr. Ward and Dr. Gerathewohl at the School of Aviation Medicine and by Dr. Schock and Dr. von Beckh of Holloman Air Force Base.

Liquid such as water in an open container presents a problem when used in the state of weightlessness. It acts with a mind of its own, showing no regard for its relation to the container. As soon as one moves the container, the liquid floats free, becoming an isolated amorphous mass. It soon breaks up into small particles, a serious matter since it can then be aspirated, literally drowning the crew member in his drinking water. A squeeze bottle such as the dispenser designed for catsup or mustard resolves this problem nicely.

Figure 1. View of the subject in the capsule prior to the MANHIGH II flight. The empty plastic bags in the foreground were used for storing sandwiches and additional miscellaneous items such as filters, camera film, pencils, etc.

Will food digest adequately under weightlessness? Certainly, yes. Food moves through the digestive tract by means of peristalsis. You can prove this rather nicely by filling your mouth with water and then placing your torso upside-down along a bed and swallowing the water. It works. This upside-down position is a more difficult situation than when one is weightless. Solid foods present one hazard. If one tries to eat a crunchy material in weightlessness, as Dr. Ward established, it forms dust in the mouth. The dust tends to drift into the nose and into the lungs. By patiently chewing to produce a semi-liquid bolus, such food then slides down without difficulty. There is apparently relaxation of the cardiac sphincter of the stomach, permitting reflux of food through the esophagus and into the mouth if even slight pressure is exerted on the abdomen during weightless-

ness. This indicates frequent small meals in space.

An obvious question follows: if one can ingest food satisfactorily, can one later excrete it in weightlessness? Experiments at the School of Aviation Medicine have verified that voiding is no problem. For those who may be experimentally minded, one can transpose the swallowing experiment and verify the fact that it works in all positions.

Weightlessness *per se* apparently will introduce no major problems or difficulties. Therefore, the general picture of what nutritional problems to anticipate in space can be realistically explored via balloon flights.

SPECIFICATIONS FOR LIVING IN A 36 x 71 INCH CAPSULE

One year before the MANHIGH II flight, I was the subject for a 24-hour claustrophobia test. It was conducted in a mock-up capsule that was the same size, 36 inches in diameter with 71 inches of head room, which just permitted me to stand up. It was an unsophisticated, preliminary test conducted at the Winzen Research Inc. plant during the summertime. The classical minimum weight and space diet for explorers over the years has been pemmican. Because it was available, it was the logical choice for the dietary staple. Because of the hot weather an ample supply of liquid was considered essential. As a concession to subject preference, the water was converted to 3 quarts of half strength grape juice. I can state categorically after this experience that a diet of grape juice and pemmican leaves a lot to be desired on a 24-hour claustrophobia flight and doubtless would in space flight as well.

At this point we solicited the advice of experts, the nutritional group at Wright Field who have been very helpful. Miss Beatrice Finkelstein recommended a low residue diet for the subject 3 days prior to the beginning of flight. She also recommended the diet carried in the capsule for both the chamber test and the flight.

THE LOW RESIDUE DIET

A partial pressure suit was required as an emergency survival device in the event of unexpected capsule depressurization. Since it had no facilities for defecation, the following low residue diet was recommended for 72 hours prior to flight. The diet was selected by Miss Finkelstein to provide foods which would be completely absorbed from the gastrointestinal tract, thereby leaving little or no bulk for the formation of feces. The basis for the high protein, low residue diet is meat, rice, eggs, sugar, small amounts of fruit juices, tea and coffee. The following schedule supplied by Miss Finkelstein was used as a guide in selecting the diet before flight.

Foods Allowed

Animal products: Beef, liver, chicken, fish

Bread: White (toasted or plain), soda crackers

Cereals: Rice, cream of wheat, noodles, macaroni

Cheese: Cottage cheese

Desserts: Gelatin, sherbets, angel food cake, sponge cake, sugar cookies

Eggs: Soft or hard cooked, scrambled, poached

Fat: Butter or margarine, not to exceed 3 tablespoons per day

Fruit: Strained fruit juices, canned peeled fruit, such as peaches or pears in limited amounts

Soup: Clear broth flavored with rice or noodles

Sweets: Sugar, jelly, in limited amounts

Vegetables: Strained vegetables such as tomatoes, peas, carrots, (not more than one serving per day); potatoes (baked or boiled).

Foods to Avoid

Coarse or whole grain breads and cereals

Cheese, other than cottage cheese

Rich desserts

Fat in excess of 3 tablespoons

Fried foods

Fruits except strained fruit juice and canned peeled fruit such as peaches or pears

Milk [a]

Tough cuts of meat

Spices, condiments, highly seasoned foods

Sugar and sweets in excess

Vegetables except strained vegetables such as tomatoes, peas, carrots, and baked or boiled potatoes

The list of foods recommended by Miss Finkelstein for the flight was as follows:

a. Two units of standard Air Force in-flight feeding, No. 8 rations
b. Four small cans of assorted fruit juices
c. Four sandwiches
d. Six candy bars
e. One can of nuts
f. Two and one-half quarts of water

In addition, the capsule check list included d-amphetamine, aspirin, and salt tablets.

A low pressure environment chamber checkout was considered an essential requirement for indoctrination and training of pilot and ground crew before the 24-hour flight. It also served as an additional check on the performance of the sealed cabin system. On this basis, the same preflight, low residue diet and food supplies were used in the chamber test at WADC as were planned for the actual flight.

PRE-FLIGHT DIET

The diet consumed before the chamber run was as follows:

24 July

0900 One segment of a small orange, 3 pieces of crisp

[a] Milk is a high residue food and should not be used in food preparation or consumed as a beverage.

bacon, 3 small cinnamon rolls, ½ pat of butter, 1 tsp. grape jelly, 1 cup black coffee

1145 1 piece toast, ½ tsp. mint jelly, 8 oz. of lemonade and saccharined coffee

1400 3 oz. of beef roast (lean), 2 tbsp. strained peas, 2 tbsp. boiled, dry potato, 1 piece of cherry pie, saccharined coffee

1900 2 crackers wet with cheese dip, 3 oz. of barbecued chicken (no skin or gristle), ⅔ finger roll, ½ pat of butter, ½ cup lemon pie filling with 2 cookies, saccharined iced tea with lemon and black coffee

2200 2 sugar cookies and 2 tbsp. chocolate ice cream

25 July

0630 1 sweet roll, 1 hamburger with catsup, lemonade

1130 1 minute steak, mashed potatoes with gravy, jello with pear, iced tea

2230 ½ lb. hamburg, dish of apple sauce, bowl of cream of mushroom soup, 1 piece of white bread and ½ pat of butter

26 July

0820 5½ oz. of pineapple juice, 1 pecan roll, black coffee

1200 8 oz. salmon steak (no skin), one dish pureed tomatoes, small bowl of clam chowder, ½ serving of jello with pear, saccharined iced tea with lemon

1430 5½ oz. of tomato juice, 4 toast Chee peanut butter cracker sandwiches, 1 hardboiled egg

2230 1 lb. t-bone choice steak, 1 saucer apple sauce, 5½ oz. V-8 juice, ⅔ of dish bread-rice pudding, saccharined coffee

The first attempt to seal the capsule was unsuccessful because of mechanical problems.

27 July

0130 2 cups of machine-vended reconstituted thin potato soup, 1 cup sugared tea, 1 egg sandwich (egg and bread only)
At this point a second attempt was made to seal the capsule for a chamber run. The following entries were made inside the capsule.

0300 Water—3 sips and 3 cookies

0400 6 more cookies, 1 cheese and peanut butter sandwich

0800 1 bacon sandwich
At approximately 1000 the capsule was reopened, and I lay down to rest while mechanical difficulties were resolved.

1400 6 fried shrimp, fried potatoes, 2 pieces of tomato, blueberry pie, ice cream, iced tea

DIET DURING THE CHAMBER TEST

Shortly after this meal I again got into the capsule for the chamber test. The capsule was closed at 1700 hours 27 July. The temperature in the capsule read 72° F., uncomfortably warm with the MC-3 pressure suit on. The information concerning this run was taken from statements made to the tape recorder within the capsule.

1810 Drank water, uncomfortably warm.

2015 I ate one of the IF rations with the comment, "This flight lunch improved the feeling toward things a lot. Makes the delays and difficulties more tolerable." By this time the temperature had gone up to 78° F.

2038 "Feeling very tired, thirsty, but too tired to get anything to drink. Too much effort. I'm just happy nobody is asking me for anything. Pretty obviously decompensated with the heat. Considered asking that they put some dry ice on the lid, almost too tired to bother even asking." The temperature was 79° F.

2114 I took two salt tablets and drank about a pint of water. Temperature still 79° F.

By midnight the temperature had dropped considerably since the refrigeration system of the chamber had been turned on. By 0400 I felt uncomfortably cold. My underwear was still soaked with sweat, and cabin temperature had dropped to 44° F.

One of the experiments conducted by Captain Archibald with the help of Dr. Nello Pace involved analysis of urine steroid content as part of a stress study. This required aliquot portions every 12 hours. At 0830 the morning of 28 July it was time to terminate a collection period by voiding. Shortly before, I had developed griping diarrhea pains every few minutes. Because of this complication I was unable to void without defecating. I decided to wait with the hope that the diarrhea would soon pass away. Repeated efforts to separate the elimination functions throughout the day were unsuccessful. Starting at 0830, I restricted my diet to chocolate drops and no liquid, hoping they would provide an energy source without stimulating peristalsis. By 1600, bladder pressure made it necessary to terminate the run.

Presumably the diarrhea came from the vending machine potato soup and pointed up the necessity of providing some emergency answer for the actual flight. A small bottle of paregoric, aluminum hydroxide gel tablets, and a plastic bag were added to the list of capsule contents. Experience from this chamber run indicated that the kind and quantity of food eaten depends strongly on conditions such as temperature and special problems that may arise.

Before the actual flight, the following preflight low residue diet was followed:

13 August

0800 2 rolls, 1 tsp. jelly, ⅛ lb. corned beef, ½ tsp. butter

Lunch Double hamburger with onions, iced tea, 12 iron tablets.

1300 Bowl of thin beef soup, 10 oz. salmon steak,

1500 1 candy bar

2000 5 cheese dipped crackers, 12 oz. of steak with ½ serving of head lettuce salad, french fried potatoes, 4 slices of tomato

14 August

0800 Coffee
two tsp. peas, 1 tsp. potato, iced tea, 12 iron tablets

Iron tablets were included because part of a cosmic radiation study included frequent blood samples of hemoglobin and hematocrit determinations. A slight drop in hemoglobin and hematocrit made fortification of the diet with iron tablets appear desirable.

1530 1 candy bar

1900 Liver paste entrée, 12 oz. sirloin beef tips, ½ serving of squash, iced tea

15 August

0800 Canadian bacon (fat removed), Bismarck roll, 1 pat of butter, coffee, 3 iron tablets

0900 Aluminum hydroxide gel tablet

1200 Aluminum hydroxide gel tablet, vitamin capsule, 3 iron tablets, 1 seconal

1900 Aluminum hydroxide gel tablet, vitamin capsule, 1 liver paste entrée, 12 oz. steak, ⅓ serving Julienne potatoes, 1 bowl thin beef soup, 2 tsp. lime sherbet, 1 roll with butter

Launch preparations continued to approximately 2300. They were cancelled when I was ready to enter the capsule.

16 August

0100 1 cold, burned cheeseburger

0900 3 wheatcakes, coffee, 1 small glass of tomato juice. Iron tablets discontinued because of mild, griping diarrhea with black tarry, well-formed stools

1530 Beefsteak, head lettuce salad with Roquefort dressing, strawberry shortcake

2000 Green beans with cheese sauce, mashed potatoes, ice cream. Launch precluded today because of bad weather.

17 August

0900 2 pieces of French toast with syrup and butter, 1 small glass of tomato juice, 2 pieces Canadian bacon, coffee

1630 Chicken liver paste, minute steak, 3 iron tablets, 2 bites of Julienne potatoes, 3 tsp. of broccoli, 1 roll with butter, iced tea

18 August

0800 Sweet roll with butter, coffee, 1 fried egg, 2 pieces bacon, small glass of tomato juice

1115 Two ½ grain seconal capsules, 2 aluminum hydroxide gel tablets

1930 Two aluminum hydroxide gel tablets

2015 Roast beef, iced tea, mashed potatoes, peas, tossed salad with Roquefort dressing

To make optimum use of the space available during the flight (Figure 2) the cans of fruit juice and the can of nuts were placed in a tray where it was necessary to use a metal grab hook to work the cans to a position where they could, but with difficulty, be grasped.

The capsule was sealed at 2245 [b] during the night of 18 August. About 15 minutes later I decided that since the 4 sandwiches had no refrigeration and would last only 12 hours at most, I might as well eat one. The first cheeseburger was finished at 2300. By 0032 on the morning of the 19th I finished the second cheeseburger. This was just after the capsule had been loaded on the truck and started on its trip to Crosby, Minnesota.

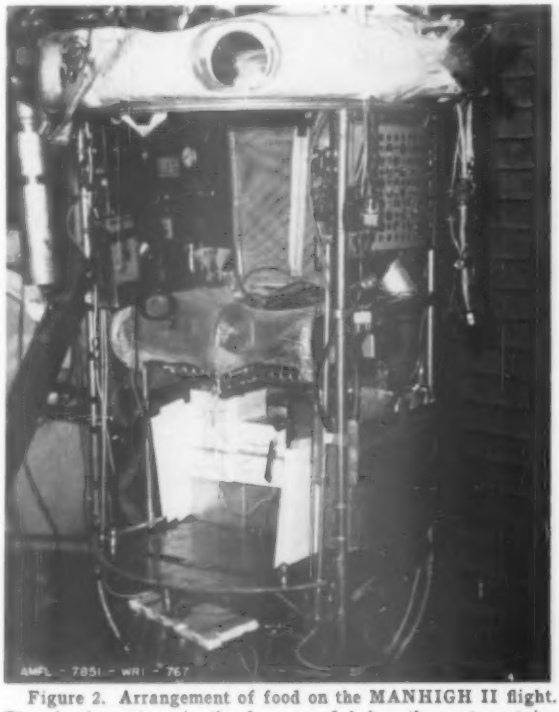

Figure 2. Arrangement of food on the MANHIGH II flight. The aluminum tray in the foreground below the seat contains cans of fruit juice and nuts. The lower can holds drinking water. The boxes of in-flight rations were stored beneath the seat with strings attached since it was impossible to reach the boxes themselves with the capsule sealed.

[b] Additional details of the flight conditions are available in the MANHIGH II final flight report in publication.

During this trip I had several cat naps and welcomed the cold night air cooling the capsule as it had become excessively hot during preparation in the Winzen plant. About 0430, shortly before reaching the iron mine, I finished the beef sandwich. By 0800 Mr. Winzen had finished inflating the balloon and had completed the preflight check when unexpected difficulties caused a delay, during which I had the bacon and tomato sandwich.

THE FLIGHT

The flight was launched at 0922. The flight required many activities—regular half-hour capsule status reports, balloon pilot responsibility for ballasting and valving, taking still and moving pictures of the scene at altitude, taking capsule stability measurements, sky brightness measurements, etc. There was always a lot more to do than time to do it in.

About 1400, Colonel Stapp, flight surgeon, asked me, "Have you eaten since the sandwich you had at eight o'clock this morning?" To my amazement I realized I had not. I had been too busy making observations to even think about eating. He said, "You'd better raise your blood sugar by eating something." The most convenient and tasty thing that was available, of course, was a candy bar—which I ate. Essentially the same scene was repeated at 1905 that evening. After 1400 the capsule became uncomfortably warm but not as severely so as during the chamber run. While I was making some observations shortly after midnight, Mr. Winzen checked to see if I had anything to eat since 1905. Again, I had been too busy making observations. I didn't care to go through the tricky procedure of extricating fruit juice or to conduct the ceremony of eating an IF-8. Instead, I finished the two remaining candy bars.

During the night the capsule descended to approximately 70,000 feet, uncomfortably close to an active thunderstorm below. Because of the low altitude, the capsule also became uncomfortably cold, requiring that I put on the 2-clo suit about 0230. Even this did not provide sufficient protection for me to remain comfortable.

Sunrise was a truly welcome sight because it meant that the helium in the balloon would expand and lift the capsule clear of the thunderstorm area. It should rise to higher altitudes where the winds would carry it westward clear of the thunderstorm.

As the capsule slowly gained altitude following sunrise, I had a renewed sense of security and thoroughly enjoyed a complete IF-8 meal. It consisted of ham and eggs, sliced peaches, and a nut roll.

With the initiation of descent at noon a number of problems arose including:

a. An unexpectedly slow response of the balloon to release of helium through the apex valve
b. Depleted battery supplies
c. An exhausted air regeneration system
d. Depleted water cooler reserves

During this period I dug out the can of nuts and nibbled on them while the balloon descended for landing. By the end of the flight there was still water left in the water can, although probably not much. The flight ended at 1732.

FUNCTIONS OF FOOD IN SPACE FLIGHT

The nature of the nutritional problem in space flight is strongly dependent on flight duration. For flights of 1–2 days duration there is no absolute requirement for a balanced diet. A temporary vitamin deficiency or negative protein balance would be of trivial consequence if the needs of the situation were fully met. Likewise, on such short flights there is little advantage in the use of dehydrated foods. Rather, they present a marked disadvantage in terms of increased complexity of preparation. However, with the extension of flight times to several weeks, water recycling will become increasingly important and with it the desirability of using dehydrated foods.

Several pertinent points have emerged as a result of the 32-hour manned flight. The feeding pattern reported on the MANHIGH II flight suggests that eating served three separate functions. During the first day of flight the pressure of making observations and the tensions inherent in the flight experience clearly reduced eating to a sustenance function. The foods selected provided a maximum of energy with the least time required to eat them. This was compatible with a crowded schedule for making observations.

In discussing the eating pattern on the MANHIGH II flight, Miss Finkelstein pointed out that the IF rations are purposely designed in accordance with crew member preference to be somewhat "fussy" so that eating can become something of a ceremony. On prolonged aircraft flights this is helpful in terms of a change in pace and a relief activity in much the same way that getting dressed for evening dinner provides a break in the daily routine that is restful and relaxing. The IF ration eaten for breakfast apparently served this purpose, but was desired on this basis only during a relatively relaxed period of flight.

The food also served a third function: that of a reward or consolation under stressful circumstances. The chocolate drops eaten toward the end of the chamber run and the nuts selected during the descent phase of the MANHIGH II flight demonstrate this. The psychology here would be quite comparable to that of the frustrated, overweight housewife who munches on tidbits of chocolate as a means of consolation.

FOOD SELECTION AS AN INDICATOR OF STRESS

A record of the type and quantity of food selected, provided all types are available, can thus serve as a revealing indicator of the status of stress and reaction of the individual to the situation. It is therefore important that foods be available that can serve all three

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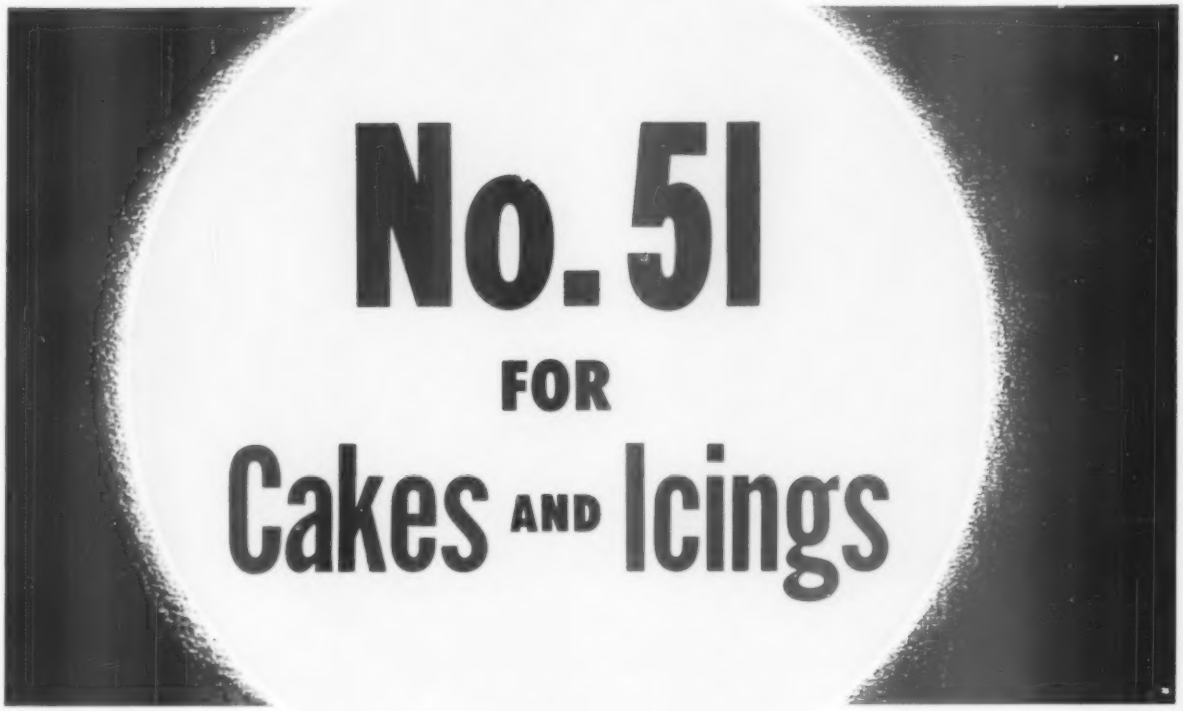

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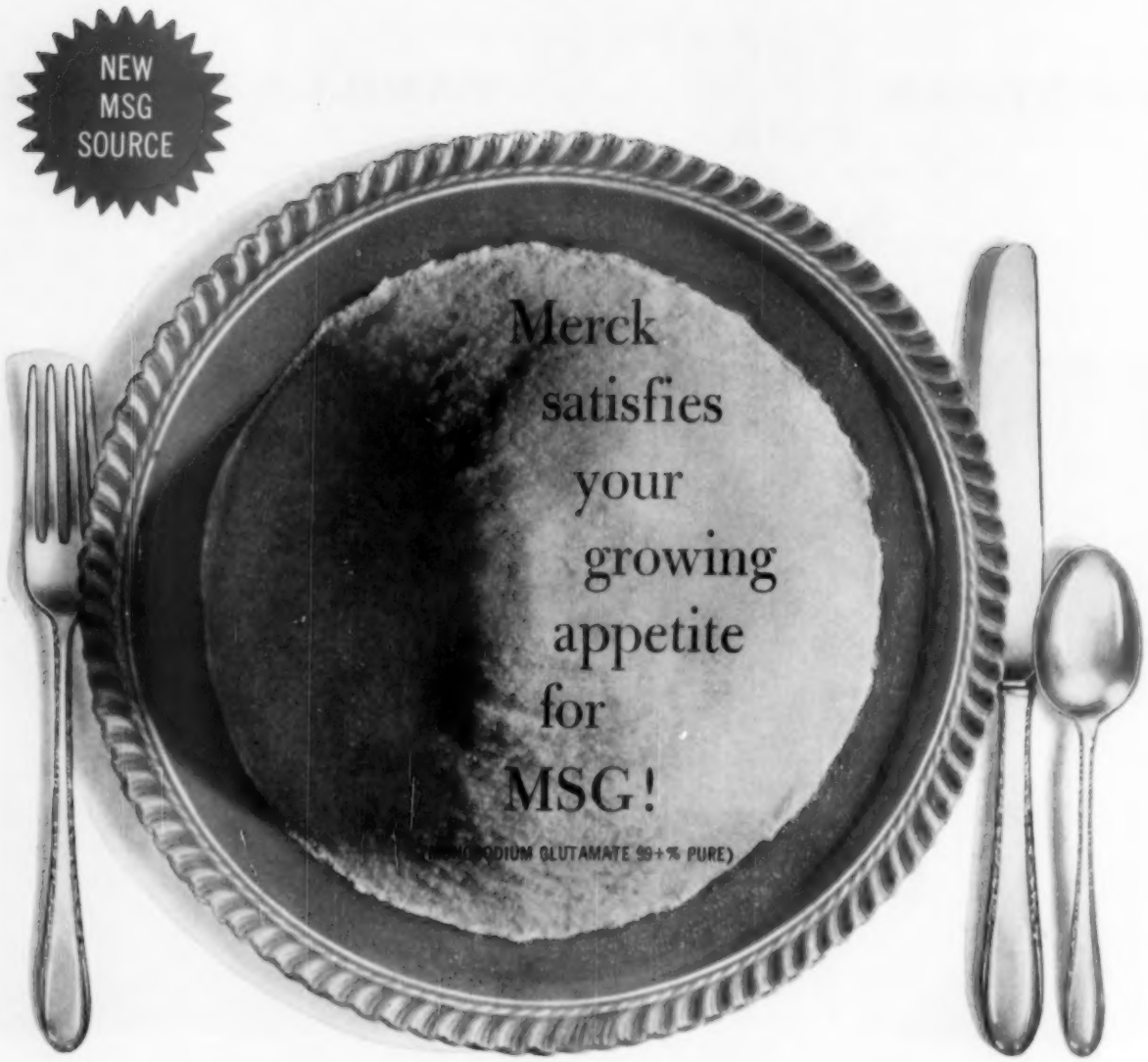

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functions so that they can best meet varying needs in addition to serving as revealing psychological indicators.

The quick energy "nibbling" material should be convenient, caloric, and provide a variety of textures. For instance, this group of foods could include candy bars, smooth, tasty, tube paste, "crunchy nut" tube paste, and stick foods such as sliced carrots. The chief difficulty encountered with the IF ration was that of opening, handling, and disposing of containers. Development of a plastic or semi-rigid container material that is more easily opened, more easily located and restrained while being used, and compressible into a minimum of space for disposal will be critically important in space flight. On the MAN-HIGH flight, there was a small garbage port which held the used containers within a plastic bag. Because of the severe limitations of space in orbital flight, the problem of disposing of containers can well become a major one after several days.

The introduction of dehydrated foods with the advent of recycled water presents a great many problems in terms of a simple procedure for reconstitution and adequate palatability. Because of the manifold stresses to which space crew members will be subjected, a readily managed, palatable diet is of prime importance. This problem becomes truly formidable with the introduction of recycled nutrients and may have to be circumvented by other approaches such as reduced metabolic rates during quiescent phases of prolonged space flight. As we gain increased experience with the more immediate problems of 1–2 day orbital flights, the nutritional limitations and challenges of more prolonged voyages will become much clearer.

Present Capabilities and Future Needs for Space Feeding*

(Manuscript received May 17, 1958)

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A PHOTON VEHICLE, driven by the pressure of light, does not exist today. Its acceleration would be very low, and generations of manned operators would guide it before the vehicle could attain velocities of a significant fraction of the speed of light. Therefore, the inhabitants will have to be prepared to propagate themselves through time as well as through space on their way to the stars. Such a vehicle could be used for interstellar travel—a state of technical and scientific accomplishment far beyond our present capabilities *(2)*. We are not ready to live in this vehicle. It poses many problems, answers to which must first be found.

SPACE

Before discussing these problems let us define the term space. Where does space begin? When are its effects noticeable?

Space begins as soon as we leave sea level. However, few of its effects are noticeable until we get to considerable heights. In general, space exists above 500,000 feet or about 100 miles above sea level. With this definition, let us venture into space. Where are we going, and how far? The moon is 240,000 miles from the earth—a distance equal to going around the earth 10 times. Venus, the nearest planet, is 100 times further, and the sun is 4 times as far as Venus. In terms of the time required for light to travel to the earth, the sun is about 8 minutes away. The closest stars are many, many times the distance to the sun, the closest being over 4 light years away *(5)*.

FOOD IN TERMS OF FLIGHT DURATION

What will travel involving these distances mean with respect to food? In order to plan for our trip, we need to know how long it will take. This will depend, naturally, not only on how far we go, but also on how fast we travel. Our speed will be at least that of escape velocity—about 25,000 miles per hour. It will be less than the speed of light—187,000 miles per second or 700,000,000 miles per hour. Since the speed of light is 34,000 times that of escape velocity, we still cannot make time estimates. Consequently, various time durations will have to be considered. For the purpose of discussion of food, we can probably best examine the problems if we divide space feeding into 3 classes based on the length of flight. First, there will be short periods of space flight lasting not more than 2 or 3 days. Second, there will be trips of intermediate duration, i.e., those of more than 2 or 3 days and extending up to some indefinite time which we can call x months. Third, there may be very long duration flights. Here we need to think in terms of space voyages which may last for years, and possibly some time in the more distant future, even for generations.

Why should we consider time periods such as these? Obviously, the duration of flight will in large measure determine the kinds of foods which may be feasible. Each of these categories of flight involves specific problems. First, however, let us think in terms of factors which will limit the duration of flight insofar as maintaining man in space is concerned. Food is not the only factor to be considered; other related needs are also pertinent.

Oxygen. Man must have oxygen every minute that he lives. Oxygen can be supplied in the most concentrated form as a liquid. A man actually utilizes about a pound and a half of oxygen a day or 550 pounds per year. Even if oxygen could be carried in weightless containers and in such form that there would be no loss, the pure logistics of carrying sufficient supplies for very long periods of time become critical in a vehicle that must escape the earth's gravitational field. As you know, many pounds of fuel and oxidizer are required to place a single pound of payload in an earth orbit. It takes even more to effect a velocity sufficient to escape the earth's gravitational field and attain true flight in space. These facts indicate that weight conservation is a highly critical consideration for space flight. We can, therefore, consider oxygen as a limitation to the duration of space flight because of its weight.

Water. Another of man's needs, and one which is more closely related to food, is his requirement for water. An average man engaged in light occupation needs about 2200 ml. of water a day. This includes the liquids he drinks and water contained in food *(3)*. In terms of weight this involves about 5 pounds per day—an amount approaching one ton per year. Consequently, when we think of length of time in space flight, water must be considered a serious limiting factor because of its weight.

Storage. When an individual eats all of his meals at home, approximately 7 pounds of food is consumed each day from kitchen supplies. This includes the weight of inedible portions of food, food lost in the process of preparation, and materials used in the packaging of these foods *(10)*. In addition, a refrigerator, a stove, and various dishes and utensils

* Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 17, 1958.

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for food storage, preparation, and service are necessary. Obviously, even for short periods of space flight, food such as that used in the home would involve excessive weight, both from the standpoint of the food itself and the equipment required for its storage and preparation. For short space flight missions, we can use ready-to-eat foods comparable to those now used in flight feeding. However, this type of food would be excessively heavy for longer periods of travel. Stored food then is a third limitation to the length of space flight.

WHAT CAN BE DONE ABOUT IT?

What can be done about these three limiting factors? Briefly, one can say that by utilizing a source of energy, the atmosphere within our space ship can be controlled. Carbon dioxide can be broken down into its constituent parts, and the released oxygen can be reutilized. Water can be recovered from the atmosphere. Water can also be reclaimed from body wastes, purified, and made safe for use. The remaining indispensable factor for man's sustenance then is food. Since it will be possible to recover water during space flight, and since our food problem is primarily one of weight, we can effect great savings in weight by the use of concentrated and dehydrated foods. Of necessity, these will be the "quick serve" type packaged in light weight containers from which the food can be eaten. By the use of dehydrated "quick serve" meals, food preparation equipment can be limited to a means for heating food. With such a feeding program, one can estimate that our former requirement of 7 pounds of packaged foods used in the home can be reduced to half that quantity for travel in space. This permits us to add dehydrate and concentrate foods to our space vehicle table as a solution to extend the time of space flight.

Now we are ready to turn our attention to space travel lasting more than 3 days. Again, we must ask the question: What are the limiting factors insofar as maintaining man in space is concerned? Oxygen can be regenerated; water can be reclaimed and made safe for use; and concentrated and dehydrated foods can be used. Oxygen and water, therefore, will not be limiting factors. But, "food economy will become critical as soon as the weight of stored foods becomes too great a penalty. This will probably be after a period of many days" *(8)*.

This period of "many days" is difficult to define with any degree of precision. At this time it remains an unknown—a value of x. However, for the purpose of discussion let us estimate that 3½ pounds of packaged concentrated and "quick serve" foods per day will provide a man with adequate nutrition, i.e., he will receive approximately 3500 calories with the usual distribution of protein, fat, and carbohydrate, and the necessary vitamins and minerals. This kind of food will involve nearly 1300 pounds of food per man per year of flight. The provision of a smaller number of calories would involve somewhat less weight; however, planning of this nature for flight in space is unrealistic. My guess would limit this x time value to 2 to 6 months. That is, it might be feasible to carry a supply of dehydrated and concentrated foods for a 2 to 6 months stay in space, but a supply to last longer than 6 months would probably exact too great a weight penalty.

A possible means of partially resolving our food-weight problem might be attained by the addition to food of substances with higher caloric densities than those of protein, fat, and carbohydrate. An approximate comparison of caloric densities of various fuels is contained in Table 1. Can any of these high energy compounds or similar substances with high caloric densities be added to foods without affecting flavor, odor, or wholesomeness of the food? What about the questions of nutrition, utility, and stability? Can such substance be metabolized? A major technical break-through would be required to answer these questions affirmatively. At this time, such a solution to our food-weight problem for feeding in space does not appear technically feasible; however, the findings of research may possibly change this negative outlook.

TABLE 1

Energy values of various fuels

Fuel	Calories per gram	B.T.U. per pound
Carbohydrate	4	2,000
Protein	4	2,000
Fat	9	5,500
Hydrazine	17	8,000
Jet Fuel	37	18,000
Boron Fuel	48	24,000
Hydrogen	100	52,000

The estimated time limitation of 2 to 6 months which has been placed on a feeding program based on dehydrated and concentrated foods might be extended by the use of synthetic diets as are frequently used in nutrition experiments with animals. Pure carbohydrates, mixtures of the essential amino acids, and fats combined with minerals and vitamins could be furnished in quantities which would provide adequate nutrition. Such feeding would somewhat decrease food-weight loads *(1)*.

One day's diet would weigh over a pound and a half, making about 570 pounds per year, and packaging materials would weigh about half as much, i.e., about ¾ of a pound. However, means would need to be devised for attaining a high degree of palatability. Even so, the provision of over 2500 pounds of food for a flight lasting 3 years is probably not feasible.

FOOD FOR THE SPACE VOYAGE OF X MONTHS TO INFINITY

Once it is no longer economical to transport food, regardless of its nature, we must think in terms of regenerating carbon and nitrogen compounds, that is, the conversion of wastes into food. Such a solution is related to the provision of oxygen for breathing. While plants produce oxygen, they also produce food for man and food for the animal life which becomes food for man. In this way we get all our oxygen and food on earth. In fact, we believe this is the source of all the oxygen in our atmosphere. Nature recycles

TABLE 2

Estimated weight of a purified synthetic diet

	Per cent of calories	Calories	Calories per gram	Gram
Amino Acids	15	525	4	131.2
Carbohydrate	52	1820	4	455.0
Fat	33	1155	9	138.3
Total	100	3500		714.5 grams or 1 lb. 9¼ oz.

water, and regenerates carbon and nitrogen compounds. This regeneration has been going on for millions of years in the great expanses of land, air, and water on the earth. A practical means to regenerate the carbon and nitrogen compounds man needs will remove all food limitations to the duration of space flight.

Certainly, in order to install such a system in our space ship, the natural processes must be speeded up and condensed into a very small space and weight. The technical feasibility of such regenerative cycling is not in question. It is well established in nature. Research, in the strict sense of the world, is not required; but technical development or applied research is needed. This development should be aimed toward utilizing processes which require the least space and weight to produce satisfactory results. The natural processes which take place on the earth to purify the atmosphere and produce our foods must be synthesized using some form of energy in a closed and balanced ecological system to be carried aboard a space vehicle.

Actually, some progress has already been made in the direction of a solution. Algae in the presence of light absorb carbon dioxide and liberate oxygen *(7)*. Work is being done now to find or produce a more efficient form of algae *(11, 12)*. There has also been considerable speculation about the possibilities of algae as a source of food *(1, 4, 6, 9)*.

TABLE 3

Space flight duration: Limiting factors and solutions

Length of flight	Limiting factors	Solutions to extend length
2 to 3 days	Liquid oxygen supplies	Regenerate oxygen from carbon dioxide
	Stored water	Recover water from wastes & atmosphere
	Stored in-flight foods	Dehydrate and concentrate foods
3 days to x months	Stored concentrated and dehydrated foods	Regenerate carbon and nitrogen compounds
x months to infinity	None	

Development of a completely regenerative, closed and balanced ecological system suitable for use in a space vehicle is a major undertaking. An aggressive program is needed to develop a practical system of food production within the confines of a space vehicle. Some important questions which must be answered are: How do algae taste? Can algae, as a sole source of food, sustain life for long periods of time? What other means of food production might be feasible? These fascinating problems present a major challenge. A multi-discipline approach utilizing food technologists, and in addition the talents of chemists, engineers, physiologists, biologists, and many others will yield a workable solution. In conclusion, it should be stated that the need for a regenerative system of feeding during space travel may possibly be some time in the future. However, work on the problem should be carried out at a rate to allow for its timely completion.

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Feeding Crews in Air Vehicles of The Future*

(Manuscript received May 28, 1958)

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FLIGHT IN AIR VEHICLES of the future will involve exceedingly high speeds and altitudes. For the human being to live and function efficiently in these projected fighter, bomber, and space vehicles, means and methods must be devised to extend man's capabilities. Research and development effort of the Aero Medical Laboratory, Wright Air Development Center is devoted to this problem. The physiology of man while operating these vehicles and also the ability of man to cope with the problems of extreme altitudes, speeds, and prolonged duration of flight are of prime interest to the laboratory. Food, nutrition, food packaging, food service equipment, and food acceptability play a vital part in both of these interests.

It is my intent to consider with you plans for feeding in fighter and bomber aircraft which will be operational in the not too distant future and also to review for you data now being obtained from basic and applied research which relate to feeding in space craft.

AIR VEHICLES OF THE FUTURE

For aircraft now being proposed and those on the drawing board considerable emphasis is placed on the comfort of the man. The science of human engineering is playing an important role in the development of future weapons systems. Airerews will operate in a cabin, the pressure of which will not exceed that at 8,000 feet. Temperatures will be controlled and will range between 80° to 100° F. Humidity will approximate 50%. Aircrew mobility will be possible. This environment will eliminate the need for protective and restrictive clothing. Present plans indicate that these aircraft will fly at extremely high altitudes and speeds for shorter periods than those high performance aircraft now in operation. However, durations of flight will be long enough to require feeding.

During short periods of flight, foods of a "nibbling" nature will suffice. Liberal quantities of water and other liquids will need to be available. For longer flights, consideration will be given to the development of full meals. The mechanics of eating during these flights should present no problem. The weight of food and the space required to store provisions will, however, present a problem of considerable magnitude. A wide variety of concentrated, precooked dehydrated foods, and "ready to serve" foods will be basic to the feeding program. Many foods will be preserved by means of cold sterilization to eliminate the need for refrigeration. Foods will be packaged in plastic and cellophane wrappers and will be eaten from the containers in which they are packaged. Minimal amounts of food service equipment will be available and that which is used will be constructed of extremely light weight materials.

Experience to be gained from feeding in aircraft now being designed represents a prelude to feeding in space ships. However, the problem of feeding in a space vehicle is an intricate one. Many answers are still needed to prevent the space voyager from being at a physiological and psychological disadvantage. These answers can only be obtained from basic research. It is my pleasure to report to you on one such study which has been completed and to give you an interim report on two others now in progress.

EFFECT OF ALTITUDE AND OXYGEN UPON TASTE

In testing special foods under operational conditions in jet powered aircraft inconsistent and erratic results were noted. In a field evaluation of the Compact Box Lunch, a sandwich type of meal, bite-size salami sandwiches were unpopular, but bite-size chip beef sandwiches were surprisingly well-liked *(1)*. This was contrary to anticipated results. When liquid meats were tested by a group of fighter pilots, acceptability was encouraging, but not high enough to indicate they should be used *(5)*. In general, foods in tablet form were poorly received by fighter pilots; but certain of these foods, like chocolate butter cream tablets, were well-liked and cheese tablets were fairly acceptable *(4)*.

As a result of these findings, a study was undertaken to correlate recognizable flight variables (reduced barometric pressure and the breathing of 100% aviator's oxygen) with controlled food ingredient levels, i.e. salt, sugar (sweet), acidity (sour), and bitterness *(2)*. These primary tastes are four of many factors affecting the acceptability of food. Other variables such as the relationship of flight stress to food prejudices and cultural food attitudes were recognized. A study of these could be most rewarding but would involve extensive research over a considerable period of time.

In lieu of such extensive research it was elected to determine the effect of reduced barometric pressure and the breathing of 100% aviator's oxygen on taste perception thresholds, taste identification thresholds, and the ability to identify the four primary tastes. Ten young male adults, selected at random, participated in this experiment. Taste tests were conducted on the ground preliminary to altitude ascent. Subjects then "ascended" in the chamber to a simulated

* Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Illinois, May 18, 1958.

altitude of 25,000 feet and were maintained at that level for a 2-hour period. During this time subjects were continuously breathing 100% oxygen. While in the altitude chamber, taste tests were accomplished at the end of the first hour and then again at the end of the second hour.

Data from this study indicated: (a) Reduced barometric pressure and the breathing of 100% aviator's oxygen do not affect the threshold of taste perception or the level of taste identification to any meaningful degree. (b) Procedures commonly used in the field evaluation of experimental foods require reexamination. This is necessary since random selection of subjects is not a reliable source for evaluating taste identities in food—particularly with respect to *sour* and *bitter*. For a true evaluation of sour and bitter tastes, a trained taste panel is required. (c) Differences in the levels of perception and identification of the 4 primary tastes do not account for the differences in acceptability of food in the air as opposed to that on the ground. Although this study is limited in scope, it is the first to correlate isolated food acceptability factors and flight variables.

NUTRITION STUDY FOR LONG RANGE AIRCRAFT

A specially designed crew compartment has been constructed at the Aero Medical Laboratory to explore the operational problems of crews flying long range, high performance vehicles. Many facets of airerew efficiency and human factors requirements are being studied. Data gained will be used to guide the weapons system planner and will also be applicable to feeding during space travel.

For purposes of this discussion remarks will be limited to the feeding and nutritional aspects of the study *(3)*. To date, two trials have been conducted. In each, 5 men have been confined to the crew compartment for a period of 5 days. During these simulated missions, subjects perform a variety of tasks. These tasks are comparable to activities essential in operating an aircraft. Tasks were selected to measure performance capacity and are carried out during the first 15 minutes of each hour and for 4 hours during 3 critical periods in the mission. All conversation between the crew members is tape recorded and all activity is televised.

A food bar in the crew compartment (Figure 1) combines storage and food preparation facilities. At the bottom of the food bar, there is a frozen food storage unit. Above, are drawers for storing non-refrigerated food. In the center, a recessed area houses a food warming oven, an electric grill and a hot cup. Above the recessed space, there are additional storage drawers. Each storage unit is color coded and assigned to an individual. A bread drawer and the freezer unit are community compartments. However, all food contained in these compartments is colored coded. Thus, food supplies are subject identified.

Each subject's food allotment provides approximately 5,000 calories per day. Subjects are free to prepare and eat food ad libitum at any time that they

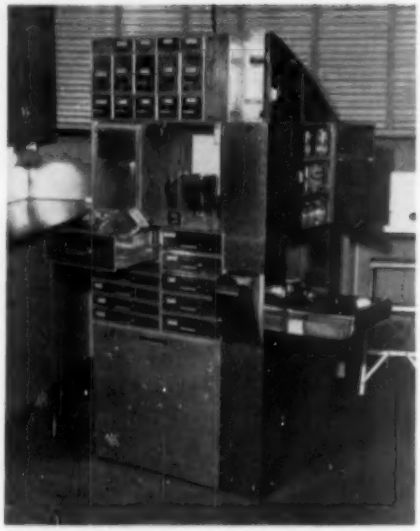

Figure 1. Food bar in the crew compartment.

are not working. All food prepared but not eaten is passed through an opening at the rear of the crew compartment. Records of plate waste are maintained. A diary is kept by each subject of foods and quantities of each consumed at meals and as snacks between meals. Knowledge of the amount of food provided, plate waste data, and food remaining at the end of the test period permit a determination of the food consumed.

Food provided in each of these trials consisted of a variety of precooked frozen meals, components of the in-flight food packet, fruit juices, soups, eggs, fresh and dried fruit, cheese, margarine, bread, and supplementary items such as cookies, candy, nuts, jam, jelly, condiments, and beverages. Foods not canned or frozen are packaged in aluminum foil and plastic materials so as to maintain freshness.

Prior to the onset of a trial, a nutritional history of each subject is taken. Within circumscribed limits, foods are provided in accordance with the subject's food likes and habits. At this time, subjects are indoctrinated concerning the feeding program. A small brochure is provided for use in the crew compartment which includes food preparation information, an inventory of available food, and a series of recommended menus. Use of food service equipment is demonstrated. At the conclusion of the test period each subject evaluates the feeding program.

Test participants thus far have expressed much satisfaction with the quantity, variety, and acceptability of the food. Of the 74 available foods, none are considered unacceptable and none have been recommended for deletion in future studies. This positive attitude is confirmed by the small amount of food left on trays.

The average food consumption per man per day during Trial 1 was 4500 calories and included 150 grams of protein. The daily fluid intake from bever-

ages, fruit juices, and soups approximated 1600 cc. per man per day. Many of these foods were consumed as between-meal snacks. Weight fluctuations of 3 subjects between the onset and the completion of the study were within normal variation. However, one subject gained 7 pounds and another 4½ pounds. A nutritional analysis of the food eaten during Trial 2 revealed that approximately 2800 calories, 100 g. of protein, and 1600 cc. of fluid from beverages, fruit juices, and soups were consumed per man per day. Quantities of food eaten at meals were less than in the previous study and there was much less snacking between meals. Body weight fluctuations of all subjects were within normal variation. Food and liquid consumption values for Trial 2 agree with recommended standards for persons engaged in sedentary activity and living in environments of comfortable temperature and humidity.

Differences in the quantity of food consumed during Trials 1 and 2 can in part be explained on the basis of group dynamics. Subjects participating in Trial 1 volunteered for the assignment. They were interested in the over-all experience of living in confined quarters for the 5-day period. Many of the subjects were persons who in one way or another were involved in the planning and construction of the crew compartment. They were a high spirited and enthusiastic group. Off duty activity, for much of the time, centered around the food bar. Food, obviously, assumed intense social and emotional significance. It represented a phase of realism. This was evidenced by the amount of conversation about food, the sorting and counting of food in the food bar, and the frequent use of the grill in making sandwiches and fruit pies. For these subjects, food remained the central source of gratification when deprived of their usual satisfactions.

Participation in Trial 2 was by assignment. Throughout the study, subjects gave the impression that they had a job to do and were performing it to the best of their ability. The group was sedate in manner, action, and social activity. Much less enthusiasm was devoted to leisure time activity. The group as a whole was task oriented. Little interest was directed towards those aspects of the experience which were not directly associated with accomplishment of the mission. It appeared that activity was concerned with matters of routine. Little, if any, use was made of the sources of extra satisfaction which were available.

Differences in food consumption may also have occurred as a result of the publicity given to the large number of calories consumed during Trial 1 and the weight gains. This may have acted as an experimental contaminant.

In summary, data conclusively indicate that adequate and highly acceptable food can be provided to crews flying long range, high performance aircraft. However, differences in the amounts of food consumed indicate the profound emotional and social significance of food in stress situations. To use a cliche, some persons will live to eat while others eat to live.

ISOLATION AND CONFINEMENT STUDY

During space travel crews will be isolated and confined to small areas for comparatively long periods of time. This will constitute an important psychological stress. Therefore, another phase of the Aero Medical Laboratory's search for significant life sciences information in space flight deals with isolation. A current study removes subjects from their usual source of sensory input, i.e. sound, sight, touch, etc. Future contemplated studies will employ varying degrees of light, sound and space, and varying tasks and sleep cycles.

Sensory deprivation is achieved by placing subjects in a dark, sound proof chamber. The chamber (Figure 2) is furnished with a bed, chair, refrigerator, and chemical toilet. Study is centered on the individuals who are isolated, how they react, and the means they employ to defend themselves against the effects of isolation. Prolonged periods of time in isolation are necessary to study these factors. Hence food becomes an important requirement. It is provided in advance. Foods which require packaging are put into plastic containers. Each food group is packaged in a different shaped container. The containers of different foods, within a specific group, are coded with masking tape and are distinguished by means of feel. Other foods, which can be distinguished by shape such as eggs or triangles of processed cheese, are wrapped in aluminum foil. Subjects are apprised of the code system (Figure 3) before entering the chamber. They are also indoctrinated as to the arrangement and placement of food, both in and out of the refrigerator.

Figure 2. Dark-isolation study: the sound-proof chamber.

Dark-isolation trials already conducted have ranged from 6 to 72 hours. At the time of writing, 35 persons have participated in the study. Food has had varying degrees of significance. Some subjects have spent excessive amounts of time eating, nibbling, or counting food; others have become very angry with the food or very fond of it. Here again, evidence is strong that food in a situation of stress may be used as a tool to obtain personal satisfactions.

Despite this psychological tie with food, calorie intakes are within normal range for persons engaged

Figure 3. Dark-isolation study: system of coding various food groups.

in sedentary activity in an environment of comfortable temperature and humidity. Subjects have consumed approximately 2800 calories per day. However, eating patterns have varied. Some subjects snack on food at frequent intervals, others maintain the customary 3 to 4 meal cycle per 24-hour period. These differences may be attributed to the fact that the subject has no way of gauging the passage of time.

Palatability and acceptability of food in many instances are contrary to that on the ground or in the air; e.g., brownies have enjoyed only a fair degree of acceptability whereas ordinarily they are highly acceptable; canned orange juice usually rates low in acceptability; in isolation it has moderate to high acceptability. Data also indicate that the ability to discriminate one food from another within the same food group is impaired. All meats taste alike. Subjects are unable to distinguish one canned fruit from another. White, whole wheat, and rye breads used in sandwiches are similar in taste. Thus it is quite apparent that removal of the visual cues ordinarily associated with eating interferes with the taste and enjoyment of food and therefore the acceptability of food.

Much effort must still be expended in determining variations in response to the stress produced by isolation. However, results will find wide application in the development of a suitable feeding program for the space voyager.

"MANHIGH II" BALLOON FLIGHT

During the summer of 1957, Lt. Colonel David Simons of the USAF ascended by balloon to an altitude of 100,000 feet.[c] Prior to this undertaking, the Aero Medical Laboratory was consulted concerning suitable food for the flight. The Compact Box Lunch, a sandwich type of meal, designed for consumption over a 20-hour period plus supplementary foods such as nuts, candy, and cookies were recommended. In addition, since this flight involved use of the pressure suit which precludes defecation, a high protein, low residue diet for 72 hours prior to take-off was recommended. The low residue diet was not adhered to absolutely but was followed in principle. It was considered helpful and effective.

Concerning the amount or kind of food eaten, the details will be omitted here since they are discussed elsewhere. But this observation on the flight will be of interest: Up to this point my interest and attention was saturated either by the requirement of piloting, and making reports or the compulsion to make scientific observations. So much so, I had eaten only snacks of sandwiches and chocolate bars. It was suggested from the Command Post that I indulge in a full IF-8 breakfast. (Air Force inflight food packet). Canned ham and scrambled eggs provided a tasty banquet floating over a sea of clouds rimmed by the blue band of topless sky *(6)*.

This reaction suggests that food can be made available for short flights into space and eating can be accomplished in a sealed cabin at 100,000 feet. For some time to come we shall no doubt have to rely on such near-space experiences as this to obtain an insight into the food attitudes of space crews.

[c] Reported in detail in the first paper of the Space Feeding session.

CONCLUSIONS

The solution to the problem of feeding in high performance aircraft and space vehicles is not nearly solved. As I have indicated our needs pertain to: (a) a greater variety of concentrated and precooked dehydrated foods; (b) further advances in the cold sterilization of food; (c) improved methods of food packaging; and (d) development of lighter weight food service equipment. In addition, a wealth of information is still needed relative to the acceptability of food when man is confronted with varying kinds and degrees of stress. These problems, as well as the many others presented at this Symposium, require your joint and co-operative action. It is my conviction that in this new, highly complicated problem the Armed Forces will be the beneficiaries, as they have been in the past, of the technical know-how of the Food Technologist.

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Closed Cycle Biological Systems for Space Feeding

I. Systems 1 and 2

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CONSIDERATION OF THE EARTH and its surrounding atmosphere convinces the observer at once that this is indeed to be regarded as a closed cycle feeding arrangement of a large magnitude. Agricultural efforts, for all their undeniable complexity, mainly produce food for man and beast along with a certain amount of waste products which are returned directly or indirectly to the land or to the sea. If the man in turn completes the cycle of conversion of agricultural products to waste using his own alimentary tract as the converter, the wastes produced usually find their way either directly into the soil or indirectly into the soil or sea through the agency of a stream, a river, or by means of some artificial waste reduction process.

In any event, agricultural products are ultimately turned into waste liquid, gases, and solids. The influence of time, dilution, microbial growth and chemical change finally completes the reduction of these waste products to a state from which they may again begin the cycle necessary to produce man's food.

These are the same waste products which maintain the growth of marine plankton which ultimately support the fish population in the ocean and the same waste products which permit the growth of plants and animals on the land.

By such a process of reasoning it appears that the earth is indeed a large closed cycle feeding system. However, all changes in this system require energy, ultimately derived from the sun; a fact which adds the dependence of power to the cyclic system existent on earth and at the same time provides the convergence component for our planet.

We may ask—how does this influence our thinking concerning space feeding? Further examination indicates great similarities between the closed cycle of the earth and that which it is conjectured may well exist in the much smaller quarters afforded by a space ship.

In the space ship we have again a closed system in which exists a human being requiring food. This human being will produce waste products which are gaseous, liquid, and solids. It will be necessary by some means to convert these waste products into food substances on long trips away from the earth. If this is not done efficiently, the system will converge upon non-utility and the space traveler may well find himself in an impossible situation.

What better method is there than to emulate the system already found in existence on the earth? If this is done, the man will be supplied food, water, and oxygen from biological and chemical systems. He will eat the food, turning out the same wastes in the space ship that are produced on the face of the earth. At this point, however, the treatment differs primarily because of the size of the population and the size of the quarters in which it is contained. It will be necessary to find waste conversion systems of relatively high efficiency which will allow the conversion of all three sources of waste material into edible products, either directly or indirectly. In the course of this waste processing it will also be necessary to provide, as is now done in the earth macrocosm, an adequate supply of water and oxygen for his use.

This complete similarity between the two situations outlined, microcosm and macrocosm, does little or nothing to make the solution of the problem easier.

When one is confronted by the necessity of setting up biological systems, the advantages of size are at once apparent. Whereas, in the earthly macrocosm, times are long, distances are great, and efficiencies may be relatively low, no such thing is true in the microcosm in question. In the space ship, efficiency is of the utmost importance. Any single factor of inefficiency may well cause the run-down of the entire space ship's cycle. Although it may be possible to use algae, or other biological systems for gas exchange and the treatment of wastes in the microcosm a tremendous amount of fundamental, as well as developmental research will be required before a clear cut outline of the problem may be completed.

From a practical point of view, the business of space feeding is not entirely new and has been discussed in the past by many authors. It has been at least a minor concern of man throughout all time to wonder about the heavens, their purpose, and their extent. Only in very recent months, however, has public attention been sharply focused on the possibility of space travel because of the historic event in 1957 when the first satellite was placed in orbit.

HISTORICAL

In May of 1957 *(22)*, a group of business men and scientists gathered at the Southern Research Institute, in Birmingham, Alabama, to discuss "The Age of Space."

The group included Dr. Ernst Stuhlinger, Army Ballistic Missile Agency, Dan A. Kimball, President of Aerojet-General Corporation and Vice President of General Tire and Rubber Company, Major General Dan C. Ogle, Air Force Surgeon General, Dr. John P.

Hagen of the Vanguard Project, and Dr. C. C. Furnas, Chancellor of the University of Buffalo. This distinguished group spent its time discussing United States and Russian missile and satellite technology, a trip to Mars, rocket power, special metals, and space medicine, but gave little or no attention to space feeding.

The Immediate Importance. Under the title of "We can have space flight in our time," Commander R. C. Truax of the U. S. Navy, has made the direct statement: *(21)* "It is obvious that a manned satellite would have military value, and much has been said along these lines since the end of the war," which sets the basic reason why the presence of man in space would be desirable. Another indication of the immediate importance of study of man in space is a quote from the *Journal of the British Interplanetary Society* printed in the *Aero Digest*, April 1956, which notes that workers of Holloman and Wright Air Development Centers "are interested in putting up an animal-carrying satellite, but it is unlikely that this will be done until the Vanguard firings are successful, also the re-entry/landing problem will have to be solved for this project."

Food. In the meantime writers on interplanetary travel seem to be taking the food problems more or less as a secondary aspect of their comments *(3, 5, 6, 8, 9, 11, 19, 21)*. A report on Professor Haldane's lecture of April 7, 1951, reads *(11)* "Food supplies would in any case weigh more than the oxygen. They would have to be carried in dry form and wetted bebefore eating . . . Both food and oxygen supplied could be continually renewed by making use of the photosynthetic activity of plants." For this purpose, Professor Haldane recommended keeping algae in a tank, "through which there would bubble carbon dioxide in intense sunlight."

Arthur C. Clarke, former Chairman of the British Interplanetary Society (1951), discussed the need for roughage in food and noted that the food ration for polar explorers came to 2 pounds, whereas in space where gravity did not exist and exercise would not be heavy, *(7)* the required food level . . . might well be below one pound a day. "Nevertheless," he adds, "we will be pessimistic and fix the amount at the polar standard." On this basis, and allowing for 2 pounds per day per man of oxygen, and water one pound per day (water to be reclaimed) he calculates "the total amount of material consumed by each member of the crew is 5 pounds per day per man, which works out for a trip to the moon, a week there, and a journey back, at a total of 250 pounds."

Burgess *(4)* merely accepts two pounds of food per man per day; Ley accepts two pounds of food per man a day plus one gallon of water.

Nicoll *(20)* in discussing the design of the compartment necessary for space travel says, "If we assume that our life compartment contains a crew of three, our next problem is to ensure that they shall have safe and breathable air for a journey lasting, say, 15 days," and then, later, "The amount of food consumed varies in a similar manner to that of the oxygen consumption, being dependent upon the amount of work being done . . . 1 lb. per man per day appears adequate. This of course would be dehydrated and of high energy content as only on long trips would a large replacement of vitamin foods be necessary." Nicoll also estimates the weight of the structure at 1,220 pounds, weight of food, O_2, and apparatus at 168 pounds, weight of water at 112 pounds, and a refrigeration plant at 56 pounds.

Haldane, speaking from personal experiments, argued that air could contain up to 3% CO_2 saying *(14)* "We conducted air analysis from time to time, and let the carbon dioxide run up to 3% or so, so as to get the utmost use from our absorbent. We emerged without headaches after 48 hours."

Regularity of eating, following a regular schedule as on earth, was suggested by Dr. Hubertus Strughold, Chief, Department of Space Medicine, School of Aviation Medicine, Randolph AFB, according to a report in *Aviation Weekly (23)*.

N. J. Bowman has an article on the use of algae for food and atmosphere control in which algae would be used to turn human wastes back into food *(3)*. Gaffron *(10)* has explored the use of algae for food directly.

Haber *(13)*, research scientist with the Department of Space Medicine, U. S. Air Force School of Aviation Medicine, actually contends that ventilation of a compartment is not the most serious problem, but that instead the problem of keeping a proper temperature is most difficult to solve.

Benson *(1)* has discussed space travel from the point of view of the Air-Force School of Aviation Medicine, of which he is Commandant. This work, already in progress well over 5 years, indicates that, "An amazingly small amount . . . less than two pounds, in fact—of an alga known as *Anacystis nibulans* will take care of (the) gas exchange activity for a single crew member indefinitely. A mass of the plant sufficient for a dozen people weighs perhaps one-eighth as much as a cylinder of oxygen."

Willy Ley *(18)* has stated that all the foods used in manned satellites will be the precooked frozen variety.

Kilbuck *(16)*, Gaume *(12)*, Lavery and Tischer *(17)*, and others have explored the possibilities of more or less closed cycle space feeding.

GENERATION OF SPACE FEEDING SYSTEMS

In considering man's requirements during extended excursions off the earth's surface, consideration must be given to at least 9 basic factors necessary to manned space travel.

1. The supply of oxygen for respiration.
2. The disposition of respired carbon dioxide.
3. The man's requirement for water.
4. The man's requirement for food.
5. Treatment of waste.
6. The psychology of stress.
7. The energy balance of the man as food, heat, work, respiration.

8. The energy balance or "run down" factor of the microcosm in which he will exist.

9. The duration of the excursion.

Of these, the first five require the establishment of mechanical, chemical or biological methods for their operation. Broad definition of these methods is made in Table 1. The remaining areas are discussed as a part of systems development.

TABLE 1

Generation of Space Feeding Systems

Parameters	
Oxygen	1. Carry as water 2. Carry as compressed oxygen 3. Recycle by chemical treatment 4. Generate using photosynthetic material
CO_2	1. Absorb chemically 2. Absorb using algae 3. Mechanical discard (compression)
Food	1. Carry all dehydrated 2. Carry part and generate part 3. Generate all biologically
Waste	1. Use all as algal food 2. Use part and dehydrate remainder 3. Dehydrate all and store 4. Ash
Water	1. Carry all 2. Recycle through chemical, mechanical or biological (algal) treatment.

Oxygen might be carried as the compressed gas in which case ease of use would be maximized, but the ratio of gas weight to necessary tank weight might be as much as 1 to 5.

Chemo-mechanical discard involves the chemical absorption of waste CO_2 followed by either compression and storage or by ejection (discard). The biological alternative is some form of culture system, probably using algae to regenerate O_2 from waste CO_2.

Plans for providing food on short excursions would involve conventional systems and conventional foods unless, as is surely possible, the various recycling systems can be brought to a high state of efficiency.

If no recycling is used, probably any food now suitable for other purposes would serve as well in this usage. Examples of this are fresh foods (fruit, lettuce, tomatoes . . .), precooked meats (frozen chicken, beef, fish . . .), mixed foods (potato salad, stews, semi-solid meat products in tooth paste tubes.) In the event that water is recycled, dehydrated foods might offer a decided weight and variety advantage over presently known recycling systems.

Water may be carried along, chemically purified or biologically purified. It is also a prime source of O_2 through electrolysis, generating at once the problem of disposing of the unnecessary H_2 resulting from the electrolytic treatment.

Table 2 outlines generally three proposed systems usable for short, medium and long excursions.

The problems generated through use of System 1 are similar in many respects to those continuously under consideration by the Armed Forces in earth-bound feeding situations.

TABLE 2

Duration of trip	
Short	*System 1.* 1. Carry all oxygen 2. Chemically absorb all CO_2 3. Carry all food 4. Store or discard liquid and solid waste 5. Carry all water
Medium	*System 2.* 1. Carry all oxygen 2. Absorb chemically all CO_2, possibly regenerating absorbent 3. Carry food 4. Waste—dehydrate, possibly ash 5. Regenerate water
Long	*System 3.* 1. Regenerate oxygen biologically 2. Regenerate carbon dioxide biologically 3. Food entirely from biological systems 4. Waste: Use all as nutrient in culture medium 5. Carry all water in cultures or biological systems.

Added to these, however, are a host of problems in engineering involving operations at low gravity values and unusual conditions of pressure and temperatures and certainly, even at this point, psychological stress and physiological problems which must not be overlooked.

System 2 is designed for excursions longer than those possible through the use of System 1. It will be noted that recycling is introduced to include regeneration of oxygen and some food. Both of these necessities would be maintained using biological recycling systems.

System 3 is designed for excursions of long duration. The limits of an excursion where this system is used would depend on the rate of convergence of the sub-systems used for regeneration.

CHARACTERISTICS OF THE THREE SYSTEMS

Descriptions of Systems 1 and 2 are included together in Part I of this study since both systems are based primarily on the use of component sub-systems presently in existence. In addition, both are intended to operate best when flights are of short or medium duration.

The third or truly closed cycle system is described in the second paper of this series.

Systems 1 and 2. Space travel depends not only on the capability of a vehicle but also on the ability of man to withstand the physical, chemical, and psychological stresses of a strange and inhospitable environment. Hazards induced by such unfamiliar phenomena as weightlessness, acceleration at many times gravity, cosmic radiation and solar debris tend to obscure the fact that man's respiratory and metabolic functions must be maintained regardless of his distance from the earth. For even the briefest excursions into space, provision must be made for an adequate supply of oxygen and the withdrawal of carbon dioxide. Somewhat longer excursions will require a supply of water, and still longer, a supply of food. It is our primary objective to examine various pathways by which man's material requirements can be

satisfied during excursions of ever increasing magnitude.

In developing this concept, recognition is given to the fact that at least 700 pounds of rocket motor is required to place one pound of satellite in orbit. (Estimates vary from 160:1 to 1000:1). While it can be assumed that improvements in this picture will be forthcoming, it is realistic to assume that weight will remain a critical factor as long as rocket power is used for propulsion. As a consequence, the development of systems of minimal weight for meeting material requirements will be emphasized. Daily material requirements to maintain a man in balance can be defined quantitatively as can the capacity of the system required to remove man's daily production of carbon dioxide. Such a gross balance sheet is shown in Table 3 for a man of somewhat less than average size.

TABLE 3
Daily materials balance for man[1] in space

IN	OUT
Total: 3615 grams	Total: 3615 grams
Water: 2400 grams	Water: 2730 grams
Oxygen: 715 grams (22.3 moles)	Carbon dioxide: 840 grams (19.2 moles)
Dry food: 500 grams (95% digestible) (2400 KCal. of which protein = 10%, fat = 35%, and carbohydrate = 55%)	Dry solids: 45 grams

[1] Age = 25 yrs. Weight = 64 kg. Height = 168 cm. R.Q. = 0.86.

It must be emphasized that the values shown in Table 3 for oxygen, carbon dioxide, waste solids, and to some extent, water, are related to the amount and composition of the food. It should be noted also that this table identifies the daily weight of carbon dioxide to be removed, but does not throw further light on the weight of the system needed to achieve this removal.

System 1. System 1, as projected in this presentation, requires that all items in the amounts needed for the entire excursion be included in the inventory at the time of departure. Minimum requirements for brief excursions are an adequate supply of oxygen and facilities for removal of carbon dioxide. Under such circumstances, the material imbalance created by lack of water and food would be insufficient to jeopardize man's performance or his physiological status. Requirements as indicated in Table 3 would demand 715 g. of oxygen per day plus the weight of a container having a suitable proportioning mechanism. In addition, a means for removing 840 g. of carbon dioxide per day from the atmosphere of the sealed passenger chamber is essential. For this removal the simplest and lowest-weight system appears to be based on absorption with lithium hydroxide according to the equation:

$$LiOH + CO_2 \longrightarrow LiHCO_3.$$

Assuming quantitative absorption, only 460 g. of lithium hydroxide would be required to remove the carbon dioxide produced by one man in the course of one day. It is assumed that adequate absorption can be achieved simply by exposing a considerable surface of lithium hydroxide to the atmosphere of the chamber. Under such circumstances the expendable inventory required (O_2 + scavenger) for a one day excursion amounts to only 1175 g., about 2.5 pounds. The consequences of water imbalance, however, are sufficient to limit travel to about one day. To establish conditions favoring material balance, the weight of expendable inventory would amount to 4075 g., about 9 pounds per day. This weight includes only the weights of oxygen, water, food and lithium hydroxide and must be increased to include the weights of containers and any other supplementary equipment.

Total weight of inventory required for an expedition into space will vary directly with the number in the crew and the duration of the flight. As the time away from the earth is increased, a point will ultimately be reached at which the weight of expendable inventory will limit the duration of flight. At this point, it becomes advantageous to examine the feasibility of recycling one or more of the components required to maintain man in physiological balance. With an efficient recycling process it should be possible for a relatively small amount of a particular component to suffice for an excursion of indefinite duration. To be feasible, however, the weight of the processing system must conform to a rigid limitation fixed by the capability of the vehicle and other elements of the load.

System 2. System 2 involves the recycling or regeneration of one or more of the components required to maintain man in material balance.

In considering a recycling operation, attention is immediately focused on water since this component makes up more than 50% of the expendible inventory. Also, unlike oxygen which requires chemical regeneration, water can be recovered by relatively simple physical processes. The use of distillation is immediately attractive. However, some unique problems may be encountered in attempting to operate conventional type stills in a gravity-less environment. This difficulty can be resolved by the use of a light weight centrifugal still which need develop only enough centrifugal force to maintain the unity of a boiling liquid phase and to move condensate into a collapsible container. Such containers are recommended because in a gravity-less state the pouring of water presents an unfamiliar difficulty. Moreover, it is probable that less than half of man's water loss will be in the liquid phase. As a consequence, other mechanisms must be used to recover water vapor from the atmosphere of the chamber. For this, consideration is given to utilizing a considerable area of surface chilled to below the dew point. The surface would be designed to exploit surface tension in order to facilitate harvesting of condensate with a device similar to a squeegee. Advantage is noted in the use of a chilled surface in connection with humidity control within the chamber and with the maintenance of a comfortable heat balance for the crew. Con-

sideration may be given to discharging liquid water into a warmed container in which capillary action could spread the liquid over a considerable surface. Water vapor developed in this container could be discharged at a chilled surface and thus not contribute to the humidity of the chamber.

Operation of the space vehicle at an internal pressure of 380 mm., which is equivalent to atmospheric pressure at 18,000 feet, will facilitate evaporation. The relatively small amount of energy required for the operation of a heat pump to maintain chilled and warmed surfaces can be developed by solar batteries. It is possible that generation of warm and cool surfaces within the space vehicle may be possible by exploiting natural radiation from the illuminated and dark sides of the vehicle.

Recycling of water can result in a weight saving of about 5 pounds per crew member per day. For excursions of considerable duration, this weight economy is far more significant than can be achieved by regenerating lithium hydroxide from lithium bicarbonate or by regenerating oxygen from carbon dioxide or even from the ultimate regeneration of food and oxygen from carbon dioxide and waste products.

With sufficient power to operate a small electric furnace, little difficulty should be encountered in converting lithium bicarbonate to lithium oxide. Such a conversion could be performed in a manner to yield relatively pure carbon dioxide which could be exhausted into space or used for photosynthetic conversions within the space vehicle. Complete regeneration of lithium hydroxide could effect a saving of about one pound per day for each member of the crew.

A dependable supply of oxygen represents one of the most critical features of space travel. If, as suggested above, the crew chamber is maintained at a pressure of 380 mm. a partial pressure of oxygen of 150 mm. would be maintained while the remainder of the pressure would be supplied by an inert gas and water vapor. The transportation of a supply of pure oxygen presents a problem. For short flights, a container of liquid oxygen could be employed. Under such conditions, the weight of the container would represent only a small part of the weight of oxygen. However, with such a light weight container the flow of oxygen is controlled primarily by the heat input to the container. The difficulty of controlling the escape of oxygen from a container of the size required for excursions of considerable duration subtracts from the attractiveness of this system. Unless cylinders are available which can provide positive control of oxygen flow and which add no more than 15% to the weight of the oxygen supply, it is recommended that oxygen for prolonged excursions be carried as water which contains 88% oxygen and which presents no storage problem. The feasibility of utilizing solar batteries for production of oxygen by electrolysis of water warrants careful consideration. As may be noted from Table 3, with a R.Q. of 0.86 the consumption of 22.3 moles of oxygen yields only 19.2 moles of carbon dioxide. Roughly, 14% of the oxygen consumed is combined as water. A system which seeks complete recycling of oxygen must recognize the need for providing a system for recovery of oxygen from water as well as from carbon dioxide.

Since 96,500 coulombs (1 faraday) are required to produce 8 g. of oxygen, the daily oxygen requirements of one crewman is equivalent to 89 x 96,500 coulombs. Assuming (a) that commercial solar batteries have a capability of 1 milliampere per cm.^{2} at a voltage in excess of the thermodynamic decomposition potential of water, and (b) that the surface of the space vehicle together with supplementary fins can be covered with solar cells to yield an area adequate to the generation of electricity in excess of 89 faradays per crew member, it becomes feasible to supply oxygen from water by electrolysis. The available radiant energy outside of the atmosphere of the earth amounts to about 114 g. cal./hr/cm^2. If this energy could be converted at moderate efficiency into electrical energy, there would be energy available for all anticipated requirements.

A survey of chemical mechanisms which might be exploited for the regeneration of oxygen from carbon dioxide is not encouraging if reactions known to develop appreciable amounts of carbon monoxide are rejected. Most attractive on theoretical grounds is the application of photosynthetic processes to the regeneration of both oxygen and food from carbon dioxide and other waste products. The exploitation of such a process for long-term space feeding will be discussed as System 3.

SUMMARY

Quantitative dimensions have been assigned to the material requirements of a man in space. For excursions of relatively short duration the weight required to fulfill these daily material requirements is estimated at 9 pounds per man. Longer excursions may warrant the installation of equipment for recycling water. This should reduce the daily expenditure to about 4 pounds per man. It is possible that this can be decreased another pound per day by regenerating lithium hydroxide used for absorption of carbon dioxide. Although it may be feasible to carry oxygen in the form of water which could be decomposed using current provided by solar batteries, the application of chemical procedures for recovering oxygen from carbon dioxide is regarded as hazardous.

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Closed Cycle Biological Systems for Space Feeding

II. System 3*

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The major problems evolved by interplanetary and orbital flights are machine reliability and the problem of maintaining a man in energy balance for the duration of the flight. This latter factor is the concern of this paper.

To maintain a man or a crew of men on a space flight will necessitate a microcosm to sustain human life at top efficiency for the desired period of time. Since all systems suffer some form of convergence, the type of system and its makeup would be dependent upon the parameters of weight, volume, and efficiency.

Vehicle payload ratio. Wernher Von Braun *(8)* developer of the Redstone and Jupiter rockets has constructed a concept of a vehicle weighing 1700 tons which would carry a 35 ton payload, including a 12 man crew on a 2.5 year round trip to Mars with "probability of safe return—greater than that for many a daring and courageous team who set out in the past seeking new lands."

Stuhlinger *(8)* has little to say about how the crew will be maintained in condition to operate and observe, and it is at this point that serious consideration must be given to the parameters of space travel.

Bearing in mind Stuhlinger's assertion that for commuter rockets which would be used to supply orbital vehicles about 160 pounds of take-off weight are required for every pound of payload, (estimates vary between 160:1 and 1000:1) a situation may be constructed in which the efficiency of carrying along supplies or of resupplying can be examined.

If we assume that each man in the crew will require each day approximately 1 pound of food, 1½ pounds

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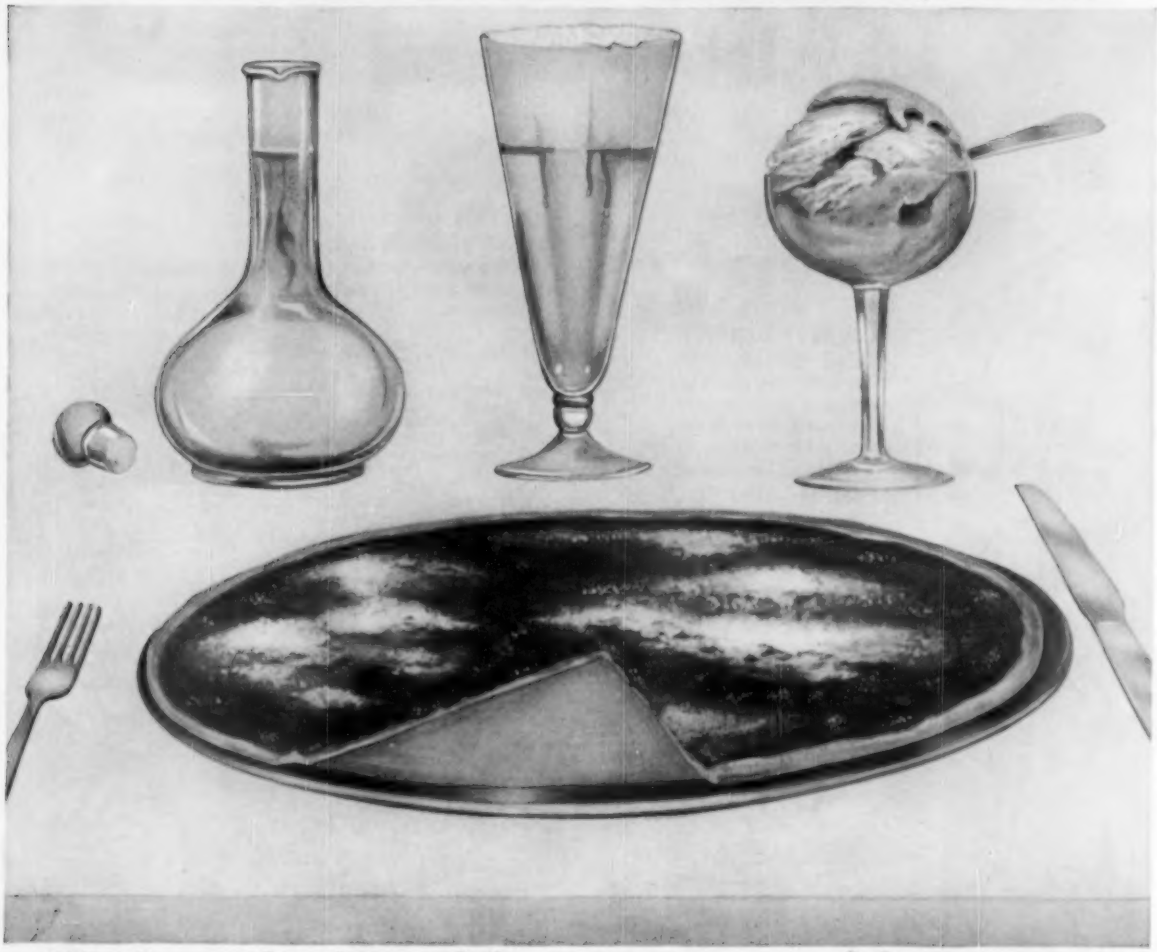

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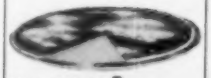

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of oxygen and approximately 4 pounds of water—the total is 6.3 pounds/man/day. This estimate is recognizably different from that made in Part I. The wide variation in these estimates is due to the paucity of exact experience and data.

Table 1 shows the influence of duration of the excursion and the number of crew members on the total weight of food, oxygen, and water required.

TABLE 1

Approximate lbs. of food, O_2 and H_2O required for 1–80 men for excursions up to 4 years duration

Days duration of excursions	Years	Number of men				
		1	10	20	40	80
1	.0027	6.3	63	126	252	504
5	.0137	31.5	315	630	1260	2500
10	.027	63.0	630	1260	2520	5000
182	.5	1150	11,500	23,000	46,000	92,000
365	1.0	2300	23,000	46,000	92,000	184,000
730	2.0	4540	45,400	90,800	180,000	360,000
1095	3.0	6840	68,400	136,800	274,000	550,000
1460	4.0	9100	91,000	182,000	364,000	730,000

If the entire 35 ton payload is given over to these types of supplies (a very unlikely circumstance) then a crew of ten men might endure a trip of three years duration but not much longer. Following the steps in the table it is apparent that increasing the crew to 20 men would shorten the allowable excursion time to the neighborhood of one year while 40 men would limit operations to 6 to 8 months.

A more tenable situation would result from the assumption that approximately 10% of the payload might be assigned to food, oxygen, water, and crew.

A glance at Table 2 indicates that a one-man space vehicle might now make an excursion of 1110 days and stay within the 10% payload limit. Correction for the weight of the man reduces this amount by only 25 days (column 5).

TABLE 2

Excursion limitations in terms of food, O_2, water and number of men in crew

Number of men	Man wt.[1] (lbs.)	Necessary food O_2 and water wt. per day (lbs.)	Days to reach payload (gross lbs.)	Days to reach payload (net lbs.)
1	150 (6850)	6.3	1110	1085
5	750 (6250)	31.5	220	198
10	1500 (5500)	63	111	87
20	3000 (4000)	126	56	32
40	6000 (1000)	252	28	4
80	12000 (−5000)	504	0	0

[1] Figures in parentheses in column 2 show the remaining allowable weight after subtraction of the crew weight.

Pursuing this observation further reveals the fact that a crew of 10 may stay away for 87 days; a crew of 20 could be gone for only 32 days.

It is worth noting that the weight of personnel figured against payload restrictions rapidly reduces flight time to very low levels and invites the planner to consider ways of conserving supplies to lower costs and, more important, to lengthen the duration of flight.

Reference to Table 1 indicates that the typical crewman in a space vehicle is here assumed to weigh 150 pounds. Other assumptions concerning the man are those found in Part I, Table 3 *(1)*.

Supply of O_2. Apart from physically carrying O_2 for initial use or emergency, the regeneration of O_2 must be accomplished for longer flights. Chemical systems at present are not sufficiently advanced to accomplish this. Most chemical regenerative systems for O_2 result in the concurrent formation of CO. Therefore, it seems more advantageous to utilize a biological system with a high unit photosynthetic efficiency.

Most plants with a high order of efficiency have some rather fastidious growth requirements so that a balance of O_2 regeneration and ease of growth will have to be compromised. Among the higher unit efficiency groups are the algae and many of the mountain plants such as *Gentiana* and *Veronica*. Plants with less fastidious growth habits but lower efficiency include some of the lichens, liverworts and mosses.

Dispcsition of CO_2. From a photosynthetic standpoint, the disposition of CO_2 is a direct adjunct of O_2 supply. Since most of the work on respiration of plants has been collated in the form of CO_2 fixation, the following table of CO_2 fixation provides some indication of the photosynthetic efficiency of plants.

The photosynthetic efficiency of algae seems unimpressive when the comparison is made on the basis of surface employed in photosynthesis. Table 3 indicates that the alga *Chlorella* may be only 1/50 as efficient as *Gentiana algicola*.

TABLE 3

A comparison of photosynthetic efficiencies of several plants *(9)*

Species	CO_2 Fixation (mg. CO_2/100 cm./hr.)
Sunflower (Helianthus annus)	5.5–24
Heliotrope (Heliotropium aeguzuides)	27
Veronica (Veronica bellidioides)	65
Gentiana (Gentiana algicola)	≥100
Chlorella pyrenoidosa	1.77

Consideration of photosynthesis on the basis of weight of tissue involved, however, reverses the emphasis because of the tremendous surface to volume ratio of the algae as compared to higher plants.

For algae (Chlorella pyrenoidosa) the CO_2 fixation is approximately 13.4 g. of CO_2 per 100 g. dry weight of algae per hour. This would mean 1.1 kg. wet weight of algae could supply one man's requirements for CO_2 removal.

Myers *(7)* calculations indicate that 2.3 kg. of *Chlorella pyrenoidosa* would be required to provide an adequate $O_2 - CO_2$ balance for one man.

Along with the removal of CO_2, such gaseous metabolic products as CO, H_2S, H_2, etc., will have to be removed.

A BACTERIAL SYSTEM

There are many types of bacteria whose metabolic cycles include chemical changes of potential use in a closed cycle feeding system. Examples of these are included in Table 4.

TABLE 4

Examples of metabolic cycles of potential use in closed cycle feeding

Microorganism	Chemical transformation
Thopiedia rosea	$2CO_2 + H_2 + \text{light} \longrightarrow 2(CH_2O) + H_2SO_4$ (4)
Hydrogenomonos pantotropha	$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$ (4)
Rhodopseudomonos palustris	CO_2 + organic matter + light $\longrightarrow$ CH_2O + oxidized organic matter (4)
Thiobacillus thiooxidans	$S + 1\frac{1}{2}O + H_2O \longrightarrow H_2SO_4$ (4)
Nitrosomonas europaea	$NH_3 + 1\frac{1}{2}O_2 \longrightarrow HNO_2 + H_2O$ (4)
Beggiatoa alba	$H_2S + \frac{1}{2}O_2 \longrightarrow H_2O + S$ (10)
Sporovibrio desulfuricans	$4H_2 + CaSO_4 \longrightarrow H_2S + Ca(OH)_2\ CO_2$ + energy $\longrightarrow$ cell material (10)
Clostridium aceticum	$4H_2 + 2CO_2 \longrightarrow CH_3COOH + 2H_2O$ (11)
Methanobacterium omelianskii	$4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$ (11)
Carboxydomonos oligocarbiphilus	$CO + \frac{1}{2}O_2 \longrightarrow CO_2$ (11)
Methanomonas methanica	$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$
Thiorhodaceae	$CO_2 + 2H_2S$ + light $\longrightarrow$ $(CH_2O) + H_2O + 2S$ (11)
Athiorhodaceae	$CO_2 + 2H_2$ + light $\longrightarrow$ $(CH_2O) + H_2O$ (11)

H_2O requirement. The regeneration of water by distillation has been discussed in Part I of this series. Other types of physical regenerative systems include absorption of impurities or ion exchange procedures.

MAN'S REQUIREMENT FOR FOOD

Regeneration of solid material to supply a source of food for space travel presents some special problems. No simple biological system which acts as a gas exchange medium would seem to be entirely satisfactory as a source of food in itself. Thus, the algae system, which seems most feasible for a gas exchange medium lacks balance for human consumption, resulting in the fact that one crew member would need to consume 9.4 pounds algae per day to satisfy his carbohydrate metabolism.

Growing algae are known to contain approximately 75% H_2O. Typical composition is shown in Table 5 *(2)*.

TABLE 5

Typical compositions of algae

Composition of dry matter	Per cent
H_2O	5.0
Na	8.0
"Crude Protein"	50.0
"True Protein"	45.5
Ether Extract	3.0
Ash	7.4
CHO	34.6

The protein efficiency of chlorella is known to be less than dried skimmilk but greater than dried brewer's yeast or peanut meal. If one assumes that algae contain 5 cal/g., then: 2500/5 = 500 g. dry weight of algae would be needed to feed one man for one day if optimum amounts of carbohydrate, protein, and fat are present.

On a wet basis this is $\frac{500}{.25} = 2000$ g. wet weight.

Most algae have between 17.8 − 20.2% of the dry weight as carbohydrate. Assuming 213.75 g. of carbohydrate would be needed for the diet of one man for one day:

$$\frac{213.75}{.20} = 1068.75 \text{ g. dry weight,}$$

and $$\frac{1068.75}{.25} = 4270 \text{ g. wet weight of algae needed}$$

to supply the necessary carbohydrate. This is equivalent to approximately 9.4 pounds of algae/man/day, a figure considerably higher than that reached if only the total of nutrients available is considered.

In view of this disparity, the functions of some higher biological systems, both for gas exchange and as a source of food bear investigation. Mosses, liverworts, and even higher ecological plants may be needed to supply necessary nutrients. They might also be used to provide nutrients for some smaller animals such as rabbits, goats, or others which could in turn be used as food for man.

The introduction of additional biological subsystems to the closed cycle feeding concept carries with it all of the risks of inefficiency or even failure inherent to each sub-system.

CONVERSION OF WASTES

In order to exist over a long period of time, it would be necessary to carry the entire food supply or to convert body wastes to useful dietary materials. This would involve the conversion of materials in the body wastes to a form that could be utilized by plant life that in turn could be utilized by the body. Conservation of energy and efficiency of utilization would seem to dictate a separation of those components of the waste into two categories, those that the body could use directly and those that could be used only in some other form.

Salts of the urine could be separated out by ion exchange methods and recovered for inclusion in the diet on a controlled basis or to maintain a proper mineral balance in a plant culture. By the use of chemical conversion and heat, organic compounds might be obtained in a form for maximum utilization. If the water balance is not maintained, a distillation process, utilizing solar energy, might be used to adjust it.

Conversion of fecal material presents a much more complex problem. The undigested portion, such as cellulose, could be separated and purified for reuse as bulk material and to maintain texture, or converted to digestible products if the diet contained sufficient bulk producing products. The cellulose could be broken down for use by man or by the plant culture. This process would have to be balanced or else there would be an increase of cellulose that could not be utilized or decrease to where bulk could not be maintained.

Soluble organic compounds would be separated into those products that could be utilized directly by the body, converted to other products that could be utilized, or converted to a form that could be utilized as culture medium. For example, certain fatty ma-

terials could not be utilized as media for an alga culture and unless converted to a usable form, would drop out of the cycle. Thus, fatty materials would present problems not encountered with the carbohydrates or some of the proteins.

Toxic materials. A very special part of the problem would be the elimination of any substances that would produce toxic effects or tend to accumulate in the human organism to dangerous proportions. Under normal conditions of changing diet and exercise, this would be rather unimportant, but where every phase of existence is based upon a precalculated balance, this becomes very important. These toxic substances must be converted or in time they will upset the balance. Likewise, certain compounds are toxic to cultures of lower plant life, even though they may not be toxic to man, and these would have to be converted to non-toxic forms before they could be used. This phase of the problem would require extensive basic research.

Body wastes would have to be sterilized in order to eliminate an imbalance within the human system and in any culture material used. The best method to accomplish this would be by steam pressure or possibly by gamma irradiation. Although sterilization might be accomplished by radiation, the shielding and handling necessary would probably be too great a problem. A very small and very efficient sterilizer would therefore appear to be the equipment to recommend. Without doubt, this same piece of equipment could be used in the chemical conversions.

It must be remembered that the cell material making up the bodies of microorganisms must be taken into consideration in working out a balance sheet, as this makes up a considerable amount of the fecal material.

Psychological stress. It is probably true that the first individuals going into space will be under severe psychological stress imposed by the flight and such novel experiences as weightlessness, day-night cycling, etc., and that hunger and the thought of food might be set aside. Therefore, the stress encountered in eating new or unusual foods will more than likely be very small and of significance only as it contributes to the picture of stress as a whole.

Man's energy balance. If conclusions are to be drawn concerning a proposed excursion, facts must be gathered, assumptions made, and measurements applied to the space man and his environment.

Table 3, Part I, *(1)* lists some of the assumptions concerning the space man—his characteristics, his demands, and his by-products.

It may be observed that the man selected is small and young and that comparatively little physical exertion is expected of him. He requires about 400 g. of food each day, consumes 700 g. of oxygen, and produces 800 or 900 g. of carbon dioxide as well as 2800 g. of waste liquids and solids. Further data on his energy balance is found in Table 6.

Microcosm "run down". In all closed cycle systems there is a definite "run down" factor or convergence. In the case of the macrocosm existing on the earth the "run down" factor is the availability of solar energy transmitted from the sun.

In a space feeding situation, the convergence of the system is most important and must be calculated to extend safely beyond the proposed duration of the flight. Factors which contribute to the convergence of the microcosm are:

1) Disposal or storage of waste
2) Loss of efficiency in the system
3) Utilization of non-cycled elements such as vitamins, growth factors, etc.
4) Hysteresis
5) Generation of toxic materials
6) Loss of power, light, etc.

Of the above mentioned factors all save the last are predictable, a fact which will materially aid in adopting any cyclic system.

The existing literature which deals with space travel indicates clearly the need for increased consideration of the "man in space." Improved estimates of systems requirements for space feeding will only be possible when a considerably more definite vehicle is described. Possession of accurate facts, or better still, existence of a well-defined plan for a manned space vehicle will make it possible to plan completely the feeding requirements of a space crewman for excursions of short to medium duration and

TABLE 6

Oxidation data per gram of subsistence *(3)*

	O_2 absorbed		CO_2 produced		H_2O produced g.	Calories per liter CO_2
	g.	cc.	g.	cc.		
Protein	1.382	966.3	1.522	733.9	0.376	5.579
Fat	2.876	2019.3	2.805	1427.3	1.071	6.629
Carbohydrate	1.185	828.8	1.629	828.8	0.556	5.047
Dietary per day	2100 Calories		65 g. protein		105 g. fat	225 g. CHO
Absorbed per day			61.75 g. protein		99.75 g. fat	213.75 g. CHO
	O_2 absorbed		CO_2 formed		Calories	H_2O formed g.
	g.	Liter	g.	Liter		
61.75 g. Pro	85.34	59.67	93.98	47.79	267	24.45
99.75 g. Fat	286.88	201.43	279.80	142.37	944	106.83
213.75 g. CHO	253.29	187.84	348.20	187.84	948	118.84
Sum	625.51	448.94	721.98	378.00	2159	250.12

to plan in detail the truly closed cycle feeding system which apparently is needed for long excursions.

RESEARCH AREAS REQUIRING EMPHASIS

Some of the research areas which demand attention in the solution of this problem are:

a. Perfection of rations which meet the specific demands of satellite or space feeding.

b. Compression of dehydrated foods.

c. Minimization of water intake required to maintain necessary performance level.

d. Consideration of diets producing a minimum of waste, a minimum of gas, and optimizing necessary performance—possibly through food and drug combinations.

e. Consideration of chemo-mechanical systems for disposition of CO_2 and waste.

f. Recycling systems for water.

g. Maximization of algal growth rate.

h. Discovery and culture of an alga having good growth rate, optimal gas exchange capabilities, and low cellulose production.

i. Preparation of acceptable foods from algae, especially by the use of biological "converters" such as snails, fish, daphnia, goats, rabbits, or other animal intermedia or through partial or complete dehydration and incorporation of pleasing flavors.

j. Engineering design and development of culture equipment including efficient light exchangers which will optimize photosynethetic activity.

k. Hydroponic growth of fresh vegetables, either alone or in conjunction with algal culture to provide fresh, highly acceptable food on long excursions.

l. Conversion of cellulose into edible saccharides.

m. Development of an efficient solar, radioactive, or other power source to produce light and heat.

n. In all three systems, careful consideration must be given to the gradual buildup of undesirable components and the gradual disappearance of essential ones.

With this analysis of space feeding concepts in hand, it should be possible to draw some conclusions concerning the future direction of these efforts.

SUMMARY

For excursions of short duration or where resupply is believed to be feasible in view of the 160:1 ratio of fuel to supplies, the system of choice seems to be that of carrying all supplies. (System 1, Part 1) Foods used would probably be adaptations of those presently available and might even be partly composed of fresh or frozen foods.

Limitations of weight, space outlined above prescribe fairly definite limits for the use of System 1, which might not be greatly exceeded.

Considered ideally, the introduction of a biological recycling mechanism contains the theoretical possibility of non-convergence which would allow excursions of limitless duration. Practically, the biological recycling mechanism will converge. The rate of convergence will depend on the best values of the critical parameters which may only be attained through keen insight and intensive, carefully vectored research.

Basic areas requiring research for providing a man in space in energy balance are listed.

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Space Feeding Problems: A Bibliography[a]

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SPACE FEEDING PROBLEMS arise from three basic conditions which must be understood before any practical solutions may be found. They are: (1) the physical conditions of the space which the flights traverse, (2) the restrictions imposed by the size and shape of the vehicle in which the flight is made, and (3) the basic food, oxygen and water needs of man during the flights. All three conditions are so closely related when approached from the view of space feeding that in a bibliography it is not possible to isolate the individual problems and cite the necessary background references for each. This bibliography, as a result, follows a different, more eclectic system in order to include a great many references which contain the information needed to think logically on the problems involved and to conduct research on the actual space feeding problems that may have to be faced sooner than might be predicted. The list is selected rather than complete.

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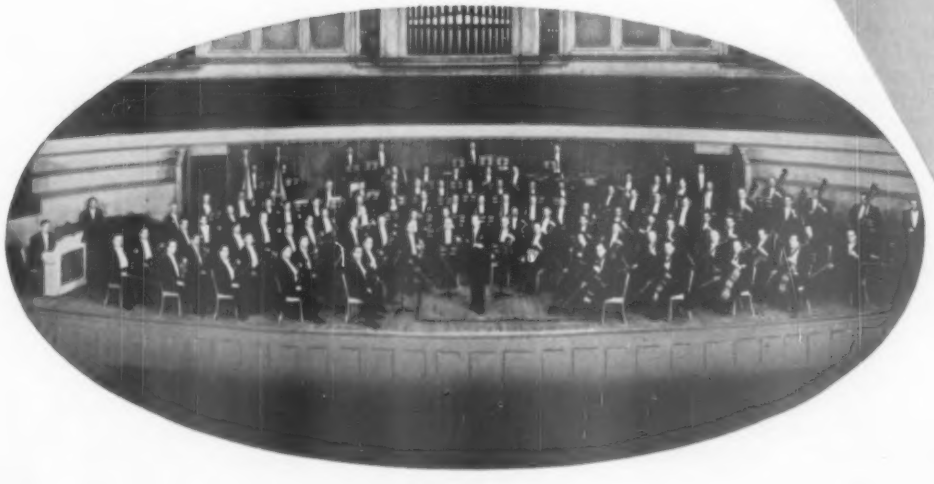

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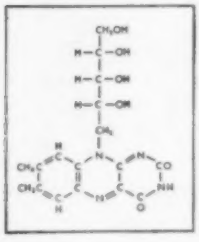
INSIDE SCIENCE

The Vital Story

A Quick History. Independent investigators, working separately to unlock several of nature's doors, sometimes open up unsuspected relationships. This happened with vitamin B_2.

Investigations. About 25 years ago, several groups, notably Warburg's, were investigating a "yellow enzyme" obtained from yeast. Almost simultaneously other investigators were studying a food factor that aided growth of laboratory animals.

What they found. Proceeding with chemical analysis of this growth factor, the team of Kuhn, György, and Wagner-Jauregg noted a relationship between the growth-producing agent and the "yellow enzyme." Their findings, and those of other researchers along similar lines, were published in 1933. Eventually, riboflavin and an essential part of the yellow enzyme were found to be identical and the unity of an essential nutrient and cellular metabolism was established.



Isolation of pure riboflavin was achieved by Kuhn and his co-workers, and by Ellinger and Koschara, in 1933.

Nomenclature. Known in the United States as riboflavin, this vitamin has also been called lactoflavin, ovoflavin, hepatoflavin, and vitamin G.

SYNTHESIS

By 1935, two eminent chemists, working separately, had synthesized riboflavin, practically in a dead heat. Prof. Paul Karrer of the University of Zurich, a collaborator of the Hoffmann-La Roche Laboratories, produced the first successful synthesis. Five weeks later Richard Kuhn of Germany announced his synthesis of the vitamin. Prof. Karrer subsequently shared the Nobel Prize in Chemistry for his work in vitamins and carotenoids.

The Karrer synthesis forms the basis for chemical processes in widespread use today by Hoffmann-La Roche and other leading manufacturers throughout the world. Riboflavin is also manufactured today by fermentation methods.

CHEMICAL AND PHYSICAL PROPERTIES

Riboflavin is yellow, slightly water-soluble with a greenish fluorescence and a bitter taste. Its empirical formula is $C_{17}H_{20}N_4O_6$. Vitamin B_2 produced by the Roche process is identical in every way with that occurring in nature.

How does vitamin B_2 work? Riboflavin is a vital part of nature's chain of reactions for utilization of carbohydrate energy. It has been found to be a constituent of many enzyme systems and is thus intimately connected with life processes. It is probably required by the metabolic processes of every animal and bird as well as by many fishes, insects and lower forms of life. (In certain animals, however, the requirement may be synthesized by bacteria within the intestine.)

In the cells riboflavin goes to work attached to a phosphate group. This substance, known as riboflavin-5'-phosphate or flavin mononucleotide, may in turn be attached to still another essential substance, adenylic acid, forming flavin adenine dinucleotide. Either nucleotide then is attached to protein, thereby forming an enzyme, and takes its part in oxidation-reduction reactions.

Requirements in Human Nutrition. As we have seen, vitamin B_2 is essential to life. We have no special storage organs in our bodies for this vitamin, although a certain level is maintained in various tissues, with relatively large amounts found in the liver and kidneys.

MEASURING METHODS

In the beginning, riboflavin activity was described in "Bourquin-Sherman units" and requirements were thought to be very small. Subsequent research showed otherwise. Milligrams of weight became the unit and the Food & Drug Administration of the U. S. Dept. of Health, Education & Welfare established (July 1, 1958) a minimum daily requirement of 1.2 mg. of riboflavin for all persons 12 or more years old. For infants it is 0.6 mg. These requirements are designed to prevent the occurrence of symptoms of riboflavin deficiency disease. The minimum daily requirement for this vitamin for children from 1 to 12 years is 0.9 milligram.

Recommended allowances. The Food & Nutrition Board of the National Research Council has recommended the following daily dietary allowances of riboflavin, expressed as milligrams. These are designed to maintain good nutrition of healthy persons in the U. S. A.

			Boys	Girls
Men			1.6	
Women			1.4	
"	(3rd trimester of pregnancy)		2.0	
"	(Lactating)		2.5	
Infants,	1-3 months		0.4	
"	4-9 "		0.7	
"	10-12 "		0.9	
Children,	1-3 years		1.0	
"	4-6 "		1.2	
"	7-9 "		1.5	
Adolescents,	10-12 years		1.8	1.8
"	13-15 "		2.1	2.0
"	16-20 "		2.5	1.9

# of VITAMIN B_2 *by* Science Writer

(Riboflavin)

Deficiencies of vitamin B_2 appear in several ways in human beings. The eyes, the skin, the nerves, and the blood show the effects of too little riboflavin. Laboratory animals have demonstrated that a riboflavin-deficient diet can cause death of adults and can slow or stop growth in the young. Female animals, deprived of riboflavin in the diet, may produce offspring with congenital malformations.

Medical uses. To overcome and control deficiencies in human beings, physicians have pure riboflavin available for administration by injection or orally, by itself or with other "B" vitamins or multi-vitamin-mineral combinations.

How do we get our daily riboflavin? Vitamin B_2 has wide distribution throughout the entire animal and vegetable kingdoms. Good sources are milk and its products, eggs, meats, legumes, green leaves and buds. Whole-grain cereals have significant but not large amounts of riboflavin.

ADDITION TO FOODS

Cereal foods play a large part in our diet. To produce the white flour almost all of us want, millers are obliged to remove parts of the wheat that contain much of the grain's riboflavin and other nutrients. In addition, cereal grains are not rich sources of riboflavin. Millers meet this problem by *enriching* the grain foods for which federal standards exist with vitamins B_1, B_2, niacin and the mineral iron. In the case of vitamin B_2, however, they do more than *restore* the processed food to its natural riboflavin level; they *fortify* the food with enough of this essential vitamin to make it nutritionally more valuable than it was in nature.

Acting to protect the good health of millions of Americans, bakers and millers adopted *enrichment* of white bread and white flour in 1941. Since that time, other foods, such as macaroni products, corn meal and grits, farina, pastina and breakfast cereals have had their food value increased by enrichment with pure riboflavin and other vitamins and minerals.

When enriching, fortifying or restoring, food manufacturers add the necessary quantity of riboflavin (and other vitamins and minerals) to the food during processing, so that the finished product meets federal, state, and territorial requirements or contributes to the consumer an amount of the vitamin that dietary experts believe significantly useful.

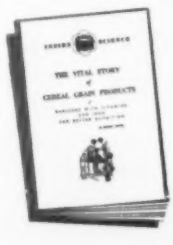
PRODUCTION

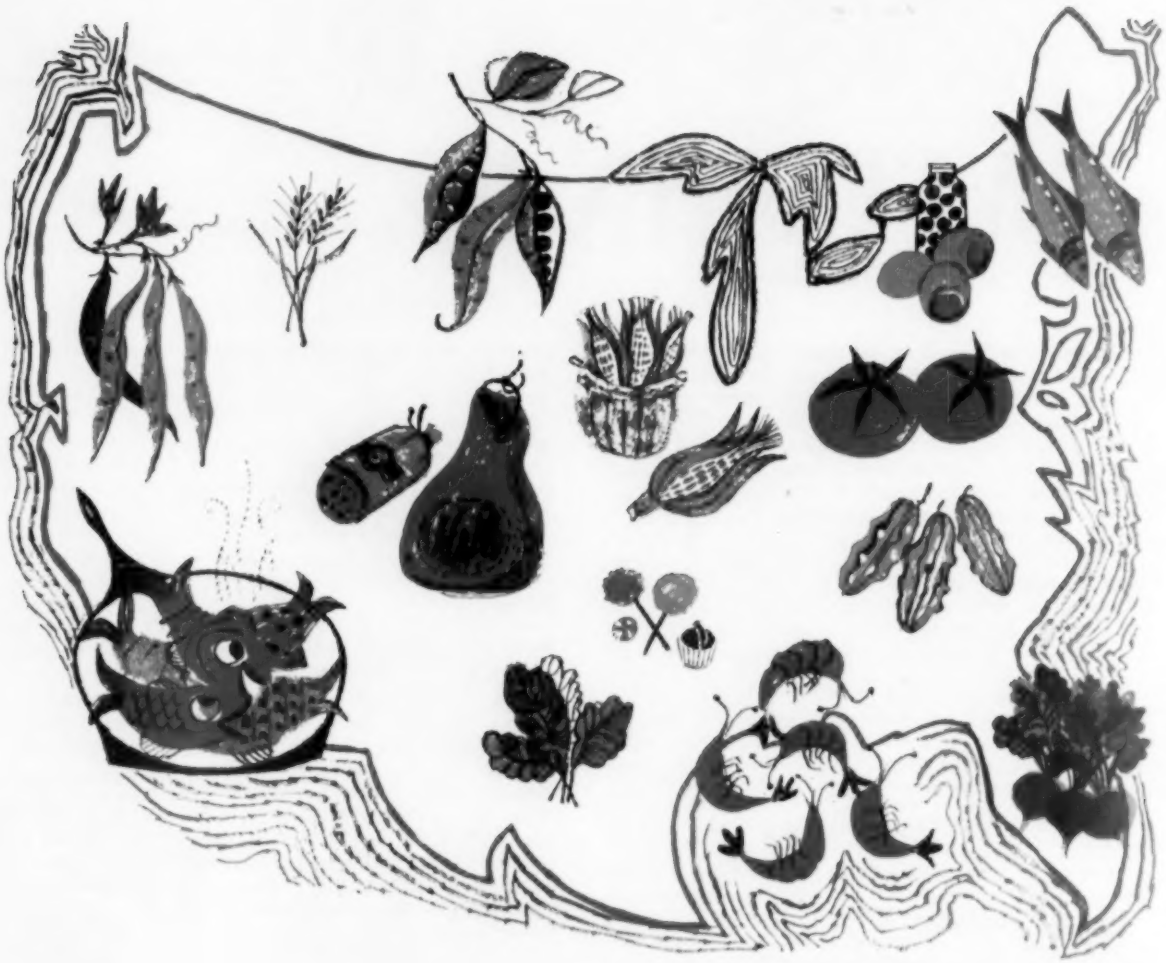
Prof. Karrer's synthesis of riboflavin was a laboratory success. Adapting the process to commercial production, however, demanded original thinking by chemists at Hoffmann-La Roche. The production of riboflavin by chemical synthesis requires the production of ribose, a rare sugar, at an early stage in the process. This special sugar must be made inexpensively if the synthesis is to be practical. Sugar chemistry is a difficult matter. In a brilliant piece of work, the Roche chemical experts developed a method to produce ribose on a commercial scale by an electrolytic process, thus overcoming a most troublesome problem. Subsequently, Roche chemists developed the first practical synthesis for riboflavin-5′-phosphate, identical with natural flavin mononucleotide.

Picture three streams joining to form a river and you have a simplified idea of the Roche process for synthesizing vitamin B_2. O-xylene and glucose are processed separately to form xylidine and ribose respectively. These are joined to form ribitylxylidine, which is then converted to ribitylaminoxylidine. Starting separately with malonic ester, which is processed through intermediate stages to alloxan, the third "stream" is then joined with ribitylaminoxylidine to form riboflavin. Purification occurs at each step of the synthesis. Riboflavin Roche equals or exceeds U. S. P. standards.

By the tons. So efficient is the Roche process that pure riboflavin is produced *by the tons* for use in pharmaceutical products and processed foods. An interesting development by Roche is the production of riboflavin in different forms related to the method of end use. Roche Regular riboflavin U. S. P. is especially useful in dry enrichment premixes, powdered dietary supplements, pharmaceutical tablets and soft gelatin capsules. Roche Solutions type is preferred for the manufacture of solutions having low concentration. Roche Riboflavin-5′-Phosphate Sodium is a highly and rapidly soluble riboflavin compound favored for all pharmaceutical liquid products and some tablets, lozenges, and capsules. It has a more pleasant taste than the bitter U. S. P. riboflavin.

This article is published in the interests of pharmaceutical manufacturers, and of food processors who make their good foods better using pure riboflavin Roche. Reprints of this and others in the series will be supplied on request without charge. Also available without cost is a brochure describing the enrichment or fortification of cereal grain products with essential vitamins and minerals. These articles and the brochure have been found most helpful as sources of accurate information in brief form. Teachers especially find them useful in education. Regardless of your occupation, feel free to write for them. Vitamin Division, Hoffman-La Roche Inc., Nutley 10, New Jersey. In Canada: Hoffmann-La Roche Ltd., 1956 Bourdon St., St. Laurent, P.Q.





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The Effect of Freezing on the Hydration Characteristics of Rice[a]

(Manuscript received March 10, 1958)

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RAW RICE CONSISTS of firm, dense grains comprised of tightly packed cells, filled largely with granules of raw starch. At the low moisture content (8 to 13%) at which the grains are stored they are hard and vitreous in appearance and able to absorb water only slowly. When the kernels are put in water, their generally solid nature serves to retard the penetration of water into their inner areas. Although cracks or fissures may be present, they are insufficient to make the grains more hydratable. This study was undertaken to determine if an increase in the porosity and ability to take up water could be brought about by subjecting the rice to freezing.

Scharling observed a century ago that when starch pastes were frozen and thawed they formed a sponge-like mass *(8)*. This knowledge was applied in 1944 *(2)* to the manufacture of surgical sponges from dilute starch pastes. After that, still other applications were made of this phenomenon; it was used to facilitate the production of dehydrated potatoes *(6)*, and for the preparation of a precooked dehydrated bean product *(4)*.

In view of the changes in structure due to the action of ice crystals *(3)* and those attributable to starch sponge formation, it was anticipated that freezing of rice grains would result in openings throughout the grains and alter their hydration characteristics. The objectives of the experimental work reported herein were therefore to test this assumption on one variety of rice, to establish the optimum conditions of treatment (water content, method of hydration, freezing techniques, and drying procedures), and to determine whether or not these conditions of treatment could be successfully applied to other varieties of rice.

MATERIALS AND METHODS

Raw materials. Fully milled, whole grain ambient air dried, Rexoro variety rice, 1955 crop, was used for the majority of the studies. But 7 other varieties were also included for comparison: MR 188 and Coloro 209, 1955 crop, obtained in the milled, whole grain state from the Western Regional Research Laboratory (U.S.D.A.), Albany, California; Zenith, Magnolia and Toro from the Rice Experiment Station, Crowley, La., and Century Patna 231 and Blue Bonnet 50 from the Rice Pasture Experiment Station, Beaumont, Texas. The last two groups were from the 1956 crop and were received in the rough (unmilled) condition. They were milled using adjustments recommended by the Grain Division of the Agricultural Marketing Service, USDA. (9 & 10) for the McGill[c] sheller and huller.

Hydration. Two methods were used to hydrate raw Rexoro rice; each one was designed to yield a set of rice samples with a wide range of water content. In one method the rice was hydrated in an excess of water at 86° and 100° C. for from 5 to 20 min. In the other method, the samples of rice were soaked in water for 10 min., steamed in an autoclave at 15 p.s.i.g. (pounds per square inch gage) (121° C.) for 15 min. and then resoaked in water for 50 min. Rice hydrated by these methods was used to study the relation of water content to behavior on freezing. In determining the effects of other variables the rice was fully cooked in an excess of boiling water until tender (about 20 min.) and then drained on a 20-mesh screen.

Freezing. To study the effect of hydration the rice was placed in 2-ounce jars, frozen for 2 hours in an alcohol bath at −25° C. ± 0.05° C., and then held for 16 hours at 1.7° C. ± 1° C. in a refrigerator prior to drying.

To determine the critical range (where the appearance of the treated grains was greatly changed) for time and temperature of freezing, the rice was placed in culture tubes (12 mm. diam. by 75 mm.) plugged with rubber stoppers, and was frozen in a thermostatically controlled alcohol bath. Ordinarily the samples were placed in the refrigerated bath previously adjusted to the proper temperature, but to obtain an exceptionally slow rate of freezing, they were put in the bath before it had been cooled. For an even more prolonged cooling period, the samples were frozen in a cabinet freezer, i.e., in still air.

Since the samples were a solid mass after freezing, it was extremely difficult to remove them from their containers without breaking many of the grains. To avoid this difficulty, the frozen material was first placed in a refrigerator overnight. The rice slowly thawed and could then be withdrawn from the containers without much damage. When this step was omitted quite different results were obtained, therefore the factor of time at 1.7° C. after freezing was included as another variable in the investigation.

The temperature of the rice was recorded on a 12-point recording potentiometer. This instrument had a temperature range of −100° F. to 250° F.; 30-gage copper-constantan thermocouples were employed and the temperature of each sample was recorded at 2 min. intervals. The thermocouples were wired to the junction box to record 4 temperatures concomitantly; 3 points were for samples and one was for the refrigerating medium.

Dehydration. In all experiments other than the one on the effect of drying temperature, samples were dried in thin layers in a well-ventilated, unheated laboratory hood. To establish the effect of different drying temperatures on the hydration characteristics and appearance of the freeze-treated rice, a forced air oven, thermostatically controlled to ± 1.5° C. was used.

Rehydration. Water uptake measurements were used to evaluate the effect of drying temperatures and to compare the effect of freezing of eight varieties of rice. A quantity of rice (1.00 g.) was placed in a test tube, 20 ml. of distilled water was added and the tube was set in a water bath at 100° C. for the desired length of time. After this treatment the contents of the tube were poured onto a 20-mesh screen and the retained

[a] Presented at the 18th Annual Meeting of the Institute of Food Technologists, Chicago, Ill., May 26, 1958.

[b] One of the laboratories of the Southern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

[c] The mention of firm names or trade products does not imply their endorsement by the Department of Agriculture.

rice was dried to constant weight (*ca.* 16 hr.) in a forced air oven at 104° C. A bath was not used for rehydration at room temperature, *ca.* 25° C.

Addition of a swelling agent. To determine the effect of a swelling agent on the changes introduced by freezing, raw rice was soaked in water at room temperature for about 30 min., steamed for 10 min. at 15 p.s.i.g., and then soaked in 2M $Ca(NO_3)_2 \cdot 4H_2O$ for 2 hr. The control was treated in the same manner except that it was soaked 2 hr. in distilled water in place of the nitrate solution. The drained rice was frozen in 2-piece aluminum containers in a cabinet freezer at −21.1° C. ± 3.3° C. for 24 hr., held for 24 hr. in a refrigerator at 1.7° C. ± 1° C. and then dehydrated at room temperature.

Examination of treated rice. The dried treated rices were examined and rated as chalky, partially chalky, or vitreous. Water uptake determinations were made on selected samples to obtain an objective measure of the changes induced by treatment.

RESULTS

Volume and appearance of freeze-treated rice are compared to that of some quick-cooking rices in Table 1 and Figure 1.

TABLE 1

Apparent specific volume of dried uncooked and cooked milled rices

Sample	Volume [1] ml.	Vol. of 1 g. ml.
Uncooked (Rexoro)	3.8	1.3
Parboiled [2]	3.8	1.3
Cooked [3]	4.6	1.5
Quick-cooking, sample A[2]	6.8	2.3
Cooked [3] and frozen	10.0	3.3
Quick-cooking, sample B[2]	10.4	3.5

[1] To obtain the volume, 3.00 g. of sample was placed in a 25 ml. graduated cylinder (Corning No. 3022) and tapped until the sample was free of large voids.
[2] Commercial long-grain products, variety of rice unknown.
[3] Soaked 30 min.; treated 10 min. at 15 p.s.i.g.; resoaked 60 min.

Grains of rice that had been cooked, frozen, and dried were chalky, much larger than the unfrozen control, and were uniformly spongy when examined with a low power microscope (60X). The change in structure was induced when the rice was hydrated to above 60% water content by the conditions shown in Table 2, frozen, held at 1.7° C. and dried. Samples with less than this moisture content present during freezing, appeared progressively less chalky, less spongy, and more vitreous as the moisture content was decreased. All chalky samples took up water rapidly upon immersion, but only those which were completely gelatinized tasted fully cooked when reconstituted. The other samples had an unpleasant grittiness and tasted slightly raw or starchy. The method and degree

TABLE 2

Hydration conditions used with freezing and result when dried

Sample No.	Hydration conditions		Moisture content (wet basis)	Chalky grains
	Time	Temp.		
	min.	*° C.*	%	%
1	20	100	77	90
2	15	100	72	95
3	10	100	65	60
4	5	100	56	30
5	20	86	68	95
6	15	86	65	99
7	10	86	61	99
8	5	86	51	99
9 [1]	10	25		
	15	121 (steam 15 p.s.i.g.)		
	50	25	61	95

[1] Sample 9 received 3 successive treatments as indicated.

of hydration prior to freezing also affected the volume and appearance of the product.

Data obtained from the study of conditions of freezing necessary to produce optimum conversion of structure indicate that chalky or spongy grains were obtained when the rice was first solidly frozen to a temperature of −6.7° C. or lower, held for 16 hours at 1.7° C. and then dried, e.g., Nos. 4 and 5 of Table 3. The total time shown in the table is the time the tubes were held in the cooling medium. Samples 7, 8 and 9 showed a progressive increase in chalkiness as the time in the cold was prolonged and/or the temperature was decreased. When these 3 samples were kept at 1.7° C. after freezing, they were even more chalky than those dried immediately after freezing. As the holding time (at 1.7° C.) was continuously increased (up to 20 hours) there was a progressive increase in the sponginess and chalkiness of the rice. This direct relationship was illustrated by Sample No. 10 (Table 3).

Both the appearance and the water uptake characteristics of the treated rice could be modified by the temperature of final dehydration. This is shown in Table 4; as the air temperature exceeded 70° C. there was a decrease in the sponginess of the finished product, until at about 100° C. there appeared to be a reversal or a loss of the benefits obtained from freezing. As chalkiness became more extensive hydratability increased.

One of the observations made with respect to drying was that the use of manual compression prior to drying was found to be an efficient preliminary procedure which subsequently required only a minimum amount of heat to complete the task. After freezing and thawing the grains were quite rubbery and were not permanently deformed when mild pressure was applied; by the use of this technique a considerable amount of liquid could be expressed without damaging the individual grains, thereafter the dehydration could be completed by heated or unheated air. In fact, immediately after thawing, the expression of water from treated grains was the only means by which changed grains (those that appeared chalky when

TABLE 3

The effect of freezing conditions on appearance

Sample No.	Freezer			Appearance when dried	
	Type	Temp.	Total time	Dried immediately	Held at 1.7° C. for 16–24 hr. then dried
		° C.	*min.*		
1	cabinet	−21.1	46	No change	Chalky [1]
2	alcohol	−1.1	108	No change	No change
3	alcohol	−3.9	184	No change	No change
4	alcohol	−6.7	122	No change	Chalky
5	alcohol	−12.2	124	No change	Chalky
6	alcohol	−1.1 ⟶ −10.0 [2]	190	No change	Chalky
7	alcohol⟶	−1.1 ⟶ −8.9	207	Chalky [3]	Chalky
8	alcohol⟶	−1.1 ⟶ −12.2	222	Chalky [1]	Chalky
9	alcohol⟶	−1.1 ⟶ −13.3	276	Chalky	Chalky
10	alcohol	−6.7	122	No change	[4]

[1] Also somewhat vitreous.
[2] ⟶ indicates the temperature was slowly lowered to that shown.
[3] More vitreous than [1].
[4] As the holding time was progressively increased from 1–20 hrs. the rice became chalkier.

TABLE 4

The effect of drying conditions on the appearance and water uptake of freeze-treated rice[1]

Drying conditions		Appearance	Water uptake [2]	
Temp.	Time		5 min. @ 100° C.	1 min. 25° C.
°C.	hr.		%	%
room temp.	6	All chalky	80	—
40	2.5	All chalky	82	76
50	1.5	All chalky	81	74
70	1.5	Mostly chalky	82	74
100	1.5	Mostly vitreous	74	58

[1] 16 hr. at −20° C., 6 hrs. at 1.7° C.
[2] Done in duplicate, figure shown is the average.

dried) could be differentiated from unchanged grains. When the latter was compressed between the fingers it was squashed, broken and sticky, and no free water could be forced out.

When fully cooked rice was soaked in calcium nitrate solution, an effective swelling agent *(1)*, it became quite rubbery and translucent. After freezing and dehydration no differences were observed between the appearance of the sample and the unfrozen control; yet another control which had not been treated with the chemical but which had been frozen, was porous and chalky-white. Evidently the presence of calcium nitrate inhibited the phenomenon which caused the structure to be modified.

There was some question as to whether the freezing treatment would be effective in modifying the hydration characteristics of other varieties of rice. Therefore, seven other rices were treated, and then evaluated by examinations for chalkiness and measurement of water uptake. Based upon observations obtained with Rexoro variety, the conditions selected were designed to provide an excessively long period of freezing (24 hr. at −21.1° C.) a holding time at 1.7° C. that was extended (24 hr.), and a drying procedure at room temperature that was very mild. In general, the hydration characteristics of these varieties were changed by freezing. The degree of modification apparently was related to grain type: the water uptake measurements shown in Table 5, and the appearance of the grains in Figure 2, revealed that the long-grain varieties, except for Toro, had the maximum amount of water uptake and were the most chalky. MR-188, a short-grain waxy variety, showed no visible change.

TABLE 5

Hydratability of selected varieties of freeze-treated[1] rice

Variety	Grain length	Water uptake [2] 1 min. at 25° C.
		%
MR-188 (waxy)	short	45
Caloro 209	short	60
Zenith	medium	51
Magnolia	medium	67
Toro	long	54
Century Patna 231	long	73
Bluebonnet 50	long	72
Rexoro	long	70
Rexoro-unfrozen control	long	47 [3]

[1] 24 hr. at −21.1° C., 24 hr. at 1.7° C., dried at 20° C.
[2] Done in duplicate, figure shown is the average.
[3] 10 min. at 25° C.

The freezing treatment was successfully applied to brown (unmilled), and to broken rice with the same success as was obtained with fully milled, whole-grain, Rexoro variety rice. In the case of brown rice, the final product differed in appearance in that it was bran-colored and non-porous or smooth on the surface (from about 30% to about 70% of the area) where the bran still remained intact.

DISCUSSION

Within the limits of the experimental conditions used, a minimum critical time temperature relation required for structural alteration was not obtained. The main conclusion to be drawn from this study was that the samples had to pass through the freezing zone very slowly; this could be accomplished either by a relatively fast freeze followed by a slow thaw, e.g., nos. 4 and 5, Table 3, or by a slow freeze and a relatively quick thaw. As an example of the latter the temperature of the samples was held just below freezing (−1° C. for 3 hours) and then lowered to subfreezing temperatures (e.g., −14.4° C). Some material (nos. 7, 8 and 9) showed more and more sponginess as the temperature was lowered after first having been held at slightly below freezing; yet no. 5, which was frozen to approximately the same temperature without the initial time at −1° C., was unchanged when dried immediately.

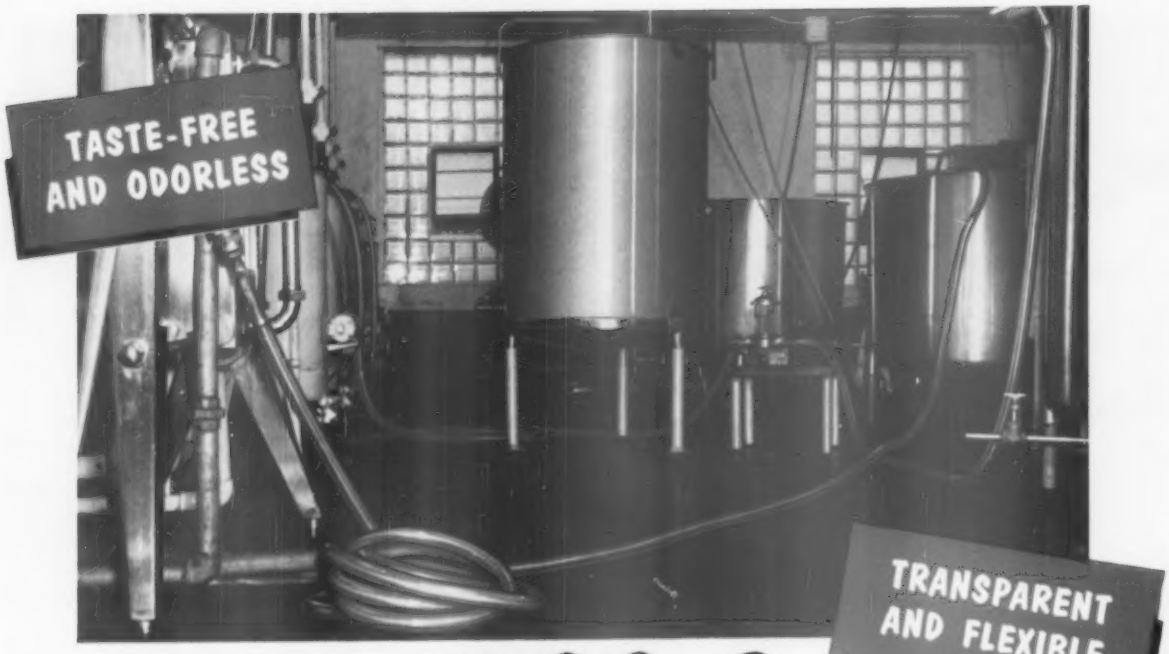
In this work rice was observed to have a tendency to become super-cooled, and it was therefore necessary to use a temperature of lower than −6.7° C. to make sure that the rice would be solidly frozen. When a higher temperature was employed the rice did not freeze, e.g., nos. 2 and 3, Table 3.

At present, adequate information is not available on the change(s) which take place in the cooked rice during freezing to describe accurately or to identify the mechanism of the change. However, there are certain similarities between this process and the phenomenon of retrogradation to cause one to postulate that both are in fact the same, or at least closely related.

The term retrogradation has been used for years. It recently has been described by Whistler *(11)* as the spontaneous precipitation of starch from solution. Retrogradation is a progressive aggregation of part of the starch forming an insoluble micro-crystalline precipitate *(5)*. The process of retrogradation is similar to the changes herein described in the following manner: both phenomena are hastened or brought about by freezing of aqueous solutions; they are arrested by swelling agents, in this case calcium nitrate; the end product, i.e., readily hydratable rice, is similar to retrograded starch in that they both may be described as opaque, fibrous and flocculent coagula; and finally amylopectin retrogrades very slowly (in fact, there is some question as to whether this component of starch retrogrades at all), thus the waxy rice (one of high amylopectin content) did not change under the conditions used in this study. One other factor which should be considered is that both the rate and extent of retrogradation is controlled to some degree, by the average size of the molecule, and also by quantitative differences in amylose content *(11)*. This may explain why differences were found in extent of change in the various rice varieties upon freezing, and also seems to exclude the possibility that structural alteration is due solely to ice crystal action.

SUMMARY

Milled and unmilled rice when gelatinized and then frozen in the presence of 60% or more water in the grain underwent structural alteration. The dried



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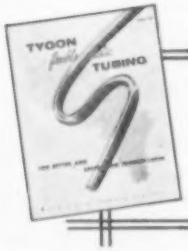

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treated grains were chalky-white, uniformly spongy, and hydrated quite rapidly with water at room temperature. Slow freezing or fast freezing followed by a slow thaw appear to be required for this alteration. The appearance and rehydration characteristics of rice treated by this method, may be controlled by variation of the conditions of freezing and/or dehydration.

Alteration of properties by this process could be inhibited by freezing in the presence of calcium nitrate, a swelling agent. The changes due to freezing were not manifested equally in different varieties of rice with marked variation of amylose content; a waxy rice with little, if any, amylose, showed the least change.

Acknowledgments

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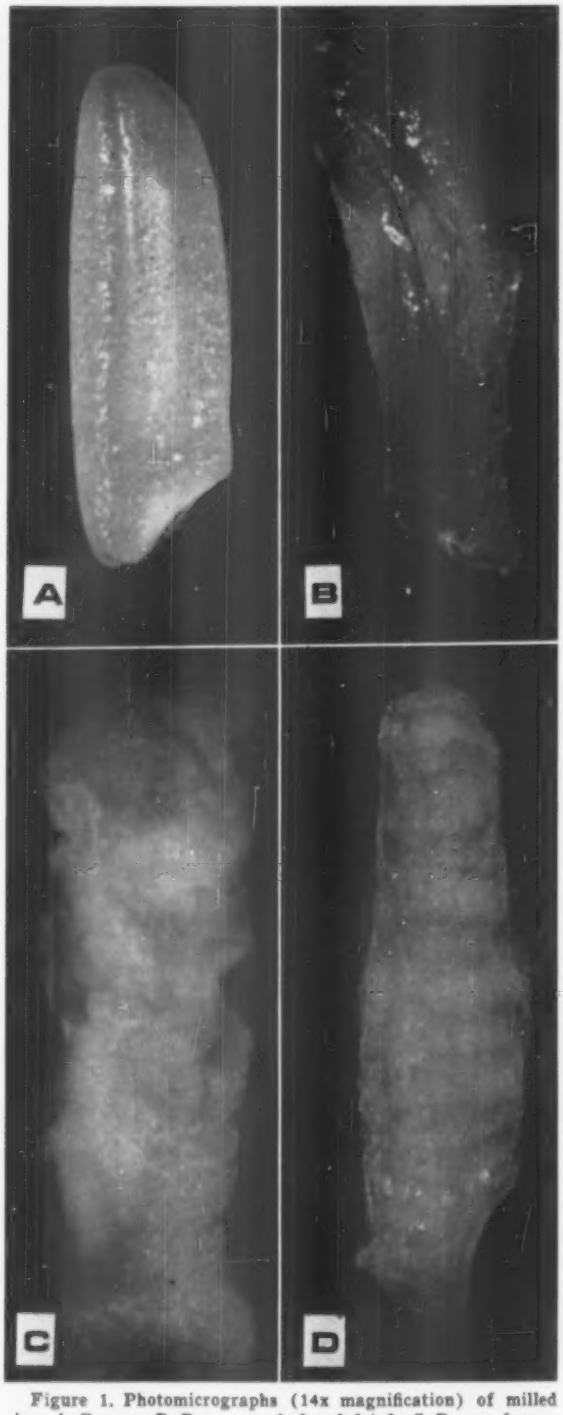

Figure 1. Photomicrographs (14x magnification) of milled rice: A. Rexoro; B. Rexoro, cooked and dried; C. Rexoro freeze-processed; D. unknown variety, commercially processed.

Figure 2. Freeze-treated rice of different varieties: Top two rows from left to right MR-188, Caloro, Zenith, Magnolia; bottom two rows from left to right Toro, Century Patna 231, Bluebonnet-50, and Rexoro.

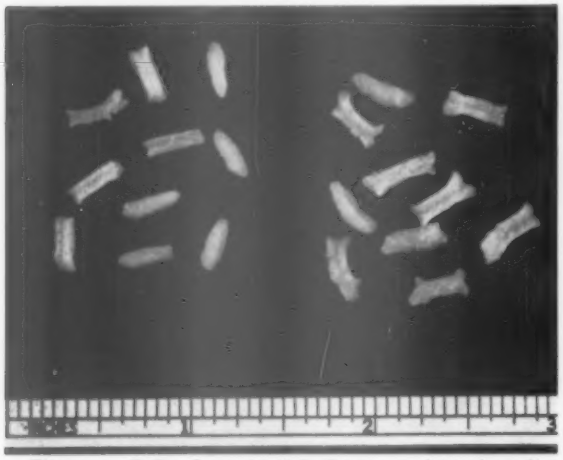

Figure 3. Left: freeze-treated, Rexoro variety rice after re-constitution and right: untreated rice cooked in an excess of water.

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Detection of Foreign Pungent Compounds

Oleoresin Capsicum, Ground Capsicum, and Chilli Spices

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(Manuscript received March 5, 1958)

Cayenne, red, and chilli peppers are used widely in foods to obtain both color and piquancy. These peppers are varieties of *Capsicum frutescens (2)*, the genus *Capsicum* belonging to the family Solanaceae, to which tomatoes and potatoes also belong. The pungent principle, capsaicin, located primarily in the veins of the fruit, is present in varying amounts in all fruits of the *Capsicum* genus, including paprika. Capsaicin itself is an extremely powerful stimulant of the chemical receptors of the palate, being reported as detectable at dilutions of one to fifteen million *(9)*; it has been consistently observed in this laboratory at dilutions of one to seventeen million.

Concentration of capsaicin in commercial chillies varies between 0.08% and 0.8% *(9)*, and corresponding variations in amounts present in oleoresins also occur. In order to provide some uniformity in the piquancy of the food which the *Capsicums* flavor, a number of tests have been developed for the determination of capsaicin. An excellent review of these methods, and an improved technique, was given by Suzuki, Tausig, and Morse *(9)*, but none of these techniques will distinguish between capsaicin and its synthetic analogues, which have widely varying pungencies *(6)*. Since synthetic analogues and intermediate compounds from the synthesis are being widely used and labelled as Oleoresin Capsicum, it is important to have a test which will distinguish between capsaicin and its analogues. The conversion of chemical or physical data to pungency, which is an organoleptic quality, can only be reliable if the specific constituents are known.

Detection of synthetic pungent principles is important to the meat packer, because synthetics cannot be used for flavoring in inspected plants *(1)*, nor can they be used in other foods for which a standard of identity has been established.

The structure of capsaicin was first determined by Nelson *(4, 5)*, and later confirmed by total synthesis *(8)*. Capsaicin is the amide of vanillyl amine and isodecylenic acid, represented by the following formula:

$$(CH_3)_2CHCH=CH(CH_2)_4\ CONHCH_2-$$

Following the determination of the constitution of capsaicin, Nelson determined the pungency of analogues made with straight chain saturated fatty acids, and concluded that the amide of pelargonic acid had approximately the same pungency as capsaicin *(6)*. Shorter and longer fatty acids had de-

creasing pungencies, as the number of carbons varied from nine.

Since capsaicin contains an unsaturated fatty acid, any means of selectively oxidizing this acid, and not affecting the vanillyl amide grouping, will destroy capsaicin but not its saturated analogues. Such a procedure follows:

EXPERIMENTAL

Selective oxidation of capsaicin. Capsaicin is separated from the oils present in the oleoresin or ether extract of chillies by extraction with 5 volumes of 70% acetic acid. For example: 10 ml. of oleoresin and 50 ml. of 70% acetic acid are shaken in a separatory funnel and allowed to separate. The acid layer is drawn off, mixed with a small amount of Celite, and filtered (Solution I). To 5 ml. of Solution I, two drops of 40% potassium chromate solution are added, stirred, and allowed to stand for 2 hours (Solution II). Two drops of Solution II are stirred into 100 ml. of water. Two to 4 ml. of water are swallowed, and if no noticeable pungency is observed, the oleoresin contains only capsaicin. If a noticeable pungency is observed, an analogue of capsaicin, such as that made from pelargonic acid, is present in the oleoresin. Solutions containing the vanillyl amide of pelargonic acid oxidized in the above manner retain their pungency for several days. When the vanillyl amide of pelargonic acid synthesized in this laboratory is used, about one third of the Scoville *(9)* pungency is lost. Consequently, if the Scoville pungency of the acetic acid solution is taken before and after oxidation, the per cent of synthetic pungency present is the ratio:

$$\frac{1.5\ (\text{pungency after oxidation})}{\text{pungency before oxidation}}$$

Verification. The constituents of oleoresins and ether extracts of chillies can be indicated by the above oxidation test. To ascertain the applicability of this test to commercial materials, it was applied to an oleoresin manufactured from chillies in this laboratory, and to an adulterated oleoresin of other origin. The adulterated oleoresin did not lose its pungency upon oxidation, whereas the genuine oleoresin did. To verify the presence of an amide of vanillyl amine other than capsaicin in the adulterated sample, the fatty acids present in the pungent principles of the two oleoresins were prepared by the following procedure, which is a modification of that used by Nelson *(4)*.

Six hundred milliliters of oleoresin and 300 ml. of 70% acetic acid are shaken and allowed to separate. The acid layer is drawn off and washed 3 times with 150 ml. of petroleum ether and filtered; 600 ml. of water are added to the washed acid layer, and it is extracted 3 times with 150 ml. of methylene chloride. The methylene chloride is combined, washed 3 times with water to remove traces of acid, and evaporated. Capsaicin or other amides are left, and if capsaicin is the only amide present it will crystallize upon seeding or upon standing a week or more. The purity of capsaicin obtained by this technique is usually greated than 95%, and it has a Scoville pungency of approximately 17,000,000. Fifteen grams of capsaicin and 80 ml. of 25% NaOH are placed in an iron bomb and heated to 180°–200° for 45 minutes. The solution is added to 400 ml. of water, and the caustic neutralized with carbon dioxide. The solution is extracted 3 times with 100 ml. of ether, and the aqueous layer evaporated to dryness. The salts are extracted 3 times with 200 ml. of ethanol, and the ethanol evaporated. The sodium salt of the acid recovered from the ethanol is dissolved in 200 ml. of water, the water acidified to pH 2, and extracted 4 times with 100 ml. of ether. The ether is evaporated, the crude fatty acid recovered by steam distillation in a Clevenger apparatus, and dried with sodium sulfate. If the pungency of the original oleoresin is about 500,000 Scoville, 4.5 to 5.5 g. of acid are recovered.

The acids obtained from the above mentioned oleoresins were used to prepare the bromide according to the procedure of Nelson *(4)*, and the amides according to a commonly used procedure *(7)*. The properties of these derivatives are noted in Table 1. Previously reported melting points are also indicated.

It is established that the adulterated oleoresin contained the vanillyl amide of pelargonic acid, and not capsaicin. The response of the oxidation test is therefore confirmed as applied to an oleoresin containing a saturated fatty acid amide of vanillyl amine.

SUMMARY

A simple and effective procedure for the detection of foreign pungent principles in Oleoresin Capsicum is reported. The procedure is based upon the selective oxidation of the unsaturated fatty acid present in capsaicin, and the resistance of saturated fatty acids and the amine portion of the molecule to oxidation under the conditions employed. It is effective in evaluating the presence of the vanillyl amide of pelargonic acid, which was shown to be the pungent principle in a commercial oleoresin. Use of this procedure will prevent misinterpretation of previously accepted methods for relating physical and chemical data to organoleptic pungency, as well as verify the authenticity of oleoresins.

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TABLE 1

Melting points of derivatives of fatty acids obtained from oleoresins of capsicum, and of fatty acids previously reported

	Genuine oleoresin	Adulterated oleoresin	Decylenic acid	Pelargonic acid
Bromide	58°–59°	No reaction	57°–59° *(4)*	No reaction
Amide	94°–94.5°	98.5°–99°	96°–97° *(4)*	99° *(3)*
Mixed m.p. with pelargonic acid amide	92°–94°	98.5°–99°		
Mixed m.p. with decylenic acid amide prepared above		92°–94°		92°–94°

Prepared Foods for the Canadian Armed Services[a,b]

(Manuscript received May 14, 1958)

R. M. Ballantyne, J. Galbraith, J. H. Hulse, W. R. Smithies, and N. E. Stacey

Defence Research Medical Laboratories, Toronto, Ontario, Canada

THE CANADIAN ARMED SERVICES, in common with the Armed Services of the United States, the United Kingdom and other Western Powers, have realized for some time the need for a revised approach to military feeding. The advent of nuclear-powered naval vessels, the increased use of airborne transportation for men and equipment and the new strategies, such as the wide dispersal and increased mobility of troops, demanded by atomic warfare, have made necessary the development of new foods and new feeding procedures.

It is most desirable that these foods should be light in weight, stable over a wide range of climatic conditions, easy to handle, and easy to prepare. Equally important, the foods should resemble closely those which are regular and acceptable components of the Canadian diet.

The following are some of the developments which, in many ways, satisfy the above requirements.

PREPARED BAKERY MIXES

The advantages of prepared cake mixes have been more than adequately presented by those who sell them to the housewife. The Canadian Armed Service cook is a cook-butcher-baker and his basic training includes no more than 60 hours instruction in baking techniques. Baking in the field and in small ships is fraught with difficulties which would tax the ability of the most skilled baker. At sea, the movement of the ship makes weighing difficult if not impossible and, in the field, conditions are rarely ideal for accurate weighing and perfect manipulation.

Thus, prepared mixes, in which all the ingredients are accurately proportioned, and the resultant doughs and batters of which are easy to handle and bake, can simplify the lot of the Armed Services cook and yield products superior on the average under many actual service conditions.

Bread Mixes

(a) *Yeast leavened.* The standard method of making pan bread in the Canadian Services is a straight-dough process. The ingredients are weighed and mixed, and the dough is fermented in bulk for 3 hours, divided, moulded, proofed and baked; the total time taken, if everything runs smoothly, is 4–6 hours. However, few, if any, of the isolated units or the small ships have temperature controlled fermentation rooms and climatic fluctuations can lead to inadequate or excessive fermentation.

The "no-time" bread-mix developed to overcome these difficulties has two separately packaged components: a "yeast mixture," and a mixture of the other ingredients. It requires only the addition of water and no bulk fermentation. The dough is mixed, immediately divided, moulded, proofed and baked, 1¾ hours being the total time taken.

In a straight dough process there is a drop in pH during bulk fermentation from about 5.9 (initial) to 5.5 (final). The pH of the dough from the bread mix is adjusted to pH 5.5 by lactic acid which is dispersed through the mix as an emulsion in shortening stabilized by a vegetable phosphatide. In addition to the time saved, the bread mix has other advantages. The dough is easier to manipulate than a normally fermented dough and the absence of a bulk fermentation period reduces greatly the dependence on environmental conditions.

Storage trials have indicated that the mix is stable for more than a year at 70° F. if it contains ordinary run-of-the-mill flour, and for at least 8 months at 100° F. if the flour is dried to below 8% moisture content. The yeast mixture has a poorer stability than the major component but, since it is a comparatively small fraction it can be conveniently stored under refrigeration or supplied more frequently by air transport.

(b) *Chemically leavened.* A Field Bread Mix, developed at DRML, is intended primarily for use where the time and facilities available are inadequate to make bread by the bread mix described above. The Field Bread Mix is complete and requires only the addition of water. It can be mixed by machine or hand, and baked in an oven or on a hot plate such as might be improvised with a sheet of metal over a fire or stove. It is baked in pieces, each about 2 oz. in weight. It can be made ready to eat within 20 minutes of starting to mix. The mix is aerated chemically and has good stability over the normal temperature range.

The mix was designed to produce bread which is acceptable hot or cold so that it may be prepared and eaten as quickly as possible. Bread baked as standard 1½ lb. loaves has to be cooled for at least 4 hours before it can be satisfactorily sliced. In Table 1 the approximate times needed for each stage of preparation of the two mixes are compared with those for a normal 3-hour dough.

TABLE 1

Times taken by different stages of breadmaking

	Bulk fermentation	Proofing	Baking	Cooling	Total
	(min.)	*(min.)*	*(min.)*	*(min.)*	*(min.)*
1. Fermented bread (3-hour dough)	180	60	40	240	520
2. DRML "no-time" bread mix	0	a) 60	15	0	75
		b) 60	40	240	340
3. DRML field bread mix	0	a) 0	15	0	15
		b) 0	40	240	280

a) as 2 oz. individual pieces.
b) as 1½ lb. loaves.

It will be noticed that mixing and moulding times have not been included since these would vary with the methods used (e.g. machine versus hand.) However, these times would be the same for the products compared and their omission from the table does not affect the validity of the comparisons. It should be pointed out, also, that the DRML Field Bread Mix is not really suitable for 1½ lb. loaves and the figures shown are therefore theoretical. They would apply, however, to any chemically leavened bread baked into loaves of this size.

Cake-cookie-pudding mix. To simplify purchasing, shipping, and storing, the objective has been to keep the number of prepared mixes to a minimum. The cake-cookie-pudding mix has

[a] DRML Report Numbers 232-1, 53–2; PCC Project Numbers D50-78-03-01, D50-78-60-01.

[b] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, May 26, 1958, Chicago, Illinois.

a low moisture and low reducing sugar content, and contains stable emulsifiers. It requires only the addition of water, egg or fruit juice and it can be baked as cake or cookies, or steamed. Other simple additions yield further flavour variations.

Variations on the mixes. Where facilities permit, the Field Bread Mix can be used to make powder biscuits, fruit and plain scones, fruit cobblers and doughnuts. With air-dried meat it will yield a meat pie dish.

The mixes may also be combined. The "no-time" bread mix and the cake mix can be combined to produce sweet dough goods.

Cost of the mixes. Limited procurements from commercial sources indicate that the mixes described are no more expensive than the equivalent quantities of ingredients demanded by Armed Services' formulae for similar baked products. The savings in labour which can be realized should result in an over-all economy when these mixes are used.

DEHYDRATED FOODS

In view of their actual or potential military importance, in bulk rations and "quick-serve" meals, over the last year stress has been laid on the study of factors relating to the large-scale production of dehydrated foods in Canada. The position at the present time is: there are adequate facilities for spray-drying and roller-drying dairy products; hot-air dried vegetables and fruits can be procured and production could be expanded without difficulty. However, no large scale freeze-drying facilities necessary for the production of a variety of dehydrated raw or cooked meats are available, and it has been impossible to procure freeze-dehydrated meats in sufficient quantity for field trials, either raw for bulk feeding or cooked for inclusion in meal and ration packs.

Hot-air dried meat. Attention has already been drawn to the value of hot-air drying for the dehydration of cooked ground meat *(1)*, prepared by the process developed in Cambridge, England, during World War II. Successful field trials have been carried out using hot-air dried beef *(1)* as a "quick-serve" item and in field kitchen recipes. Satisfactory hot-air drying and other necessary facilities have been made available by a Canadian manufacturer of dehydrated vegetables. In this way experience with dehydrated meat products can be obtained by the Canadian Armed Services, in spite of the lack of freeze-dried items.

Production of hot-air dried ground beef or pork is carried out by stewing meat cubes or slices 1 inch to 2 inches in thickness for 30 minutes, grinding coarsely, restoring the fat-free concentrated gravy and drying at a temperature of 180° F. (initial) reduced to 160° F. (final). The optimum fat content is 25–30% although beef and pork containing 35% fat on a dry weight basis have been dehydrated in hot air without difficulty.

Dehydration of several grades of beef of different cuts has shown that *cutters and canners* grade is not acceptable. The fat content is, on the average, too low and much difficulty is experienced in removing all potentially hard pieces of tissue and connective tissue. An inexpensive commercial grade of cow beef of "butcher" quality, 3–5 years of age, has been found to be satisfactory and after drying gave a product of quality similar to that produced from Blue Brand (good grade) beef.

Studies have been carried out on the storage stability of both hot-air dried and freeze-dried cooked ground beef prepared from the same sample of beef round, Canadian Blue Brand (good grade), and the results are given in Table 2.

One portion was hot-air dried to 3.9% moisture content and a part of this adjusted to 5.6% moisture by mixing with the calculated amount of water. The second portion was freeze-dried to 1.0% moisture and a part adjusted to 3.9%. Samples, each of approximately 8 oz., were stored in sealed No. 2½ cans. Clear cut changes occur on storage at 100° F. The product first develops a pleasant roast flavour which gradually changes to an unpleasant burnt flavour accompanied by a tougher dry texture. Meat of moisture content 5.6% had a slightly burnt flavour and dry texture after storage for 6 months at 100° F. Samples of lower moisture content, both air-dried and freeze-dried, showed little deterioration after this length of storage and are therefore suitable for inclusion in packaged rations.

TABLE 2

Storage data on dehydrated cooked ground beef[1]

Method of drying	Moisture[2]	Storage time	Storage temperature	Vacuum in can	Acceptability rating of reconstituted meat[3, 4]
	%	*(months)*	*(° F.)*	*(inches)*	
Hot-air	3.9	0	....	....	6.9
Vacuum-freeze	1.0	0	....	....	6.2
Hot-air	5.6	6	0	25	6.9
Hot-air	5.6	6	100	25	5.6
Hot-air	5.6	6	100	0	5.1
Vacuum-freeze	1.0	6	0	25	7.1
Vacuum-freeze	3.9	6	100	25	6.4
Hot-air	3.9	6	100	25	6.0
Vacuum-freeze	1.0	12	0	25	6.3
Vacuum-freeze	1.0	12	100	25	6.1
Vacuum-freeze	3.9	12	100	25	5.6
Hot-air	3.9	12	100	25	4.6

[1] Fat content of the samples 25%.

[2] Moisture contents on a "non-fatty solids" basis, 1.3, 5.2 and 7.5% respectively.

[3] Measured on a 9-point hedonic scale ranging from 1, *dislike extremely* to 9, *Like extremely*.

[4] Bracketed figures determined at the same panel.

After 12 months' storage, the freeze-dried products remained acceptable but the hot-air dried meat of 3.9% moisture content had developed typical signs of deterioration.

Table 2 shows that there was little difference in the acceptability of hot-air dried meat of 5.6% moisture stored for 6 months, whether canned under vacuum or not. This isolated observation was supported by storage tests done on commercial soup mixes packed in conventional pouches to which hot-air dried cooked ground beef or chicken had been added at a level of 12%. The samples were satisfactory after storage for 3 months at 100° F. which was the full length of the experiment. It is possible, therefore, that satisfactory storage life may be obtained without rigorous exclusion of oxygen from the package atmosphere.

All samples of dehydrated cooked ground beef under storage, including those in which a deterioration in flavour and texture had taken place, rehydrated readily on soaking in hot water or simmering for 5–10 minutes.

Acceptable "quick-serve" meals have been developed making use of hot-air dried beef or chicken in combination with instant potato, rice or noodles, or precooked dehydrated vegetables. Several varieties of meat bars have been prepared including beef and pork, beef with onion flavour, pork with sausage flavour, and chicken.

FREEZE-DEHYDRATION

The dehydration of raw meat or cooked meat pieces requires the use of freeze-drying. Large scale dehydration of meat and other foods in Canada would require the set up of special facilities for the purpose.

In essence the freeze-drying equipment consists of a vacuum chamber fitted with heating shelves on which the material is laid for drying, together with pumping equipment capable of reducing the pressure in the chamber to below 1 mm. of mercury. A rapid

freeze-drying process, which has been described in full elsewhere *(1, 2)*, makes use of plates fitted with aluminum spikes between which the meat slices are laid and frozen. During the drying cycle, under vacuum, heat is conducted uniformly and efficiently through the spikes into the slice to provide heat of sublimation. Drying occurs not only from the surface inwards but around each spike and, for slices up to 1 inch in thickness, may be completed in 3–5 hours, as opposed to from 16–48 hours for the conventional process .

Development work has continued using larger spiked plate units or "sandwiches" each capable of holding up to 9 lbs. of meat. Spikes of ⅛ inch diameter have been found satisfactory in so far as they have considerable strength; they leave holes in the meat but these close up and are not easily distinguished after rehydration and cooking.

Designs for a pilot plant freeze-drier making use of spiked plates for rapid freeze-drying have been under study. The spiked plates would be loaded separately and inserted between the heating shelves for the drying process. The general characteristics would be as follows: batch size, 200–300 lbs.; individual spiked plate capacity 8–10 lbs.; number of spiked plate units required per batch, 20–30; length of drying cycle, 5 hours; drying capacity per 24 hours, 800–1200 lbs. This size is suitable for operation by one man and larger scale production could be handled conveniently by a number of such units.

Economic Aspects. In order to estimate the cost of freeze-drying with such equipment, it has been assumed that it would be installed in existing factory premises, where water and electrical services could be provided. In the absence of knowledge as to whether the facilities available would be suitable for steam ejector pumps, plans have been made to provide an ice condensation unit separate from the vacuum chamber and backed by mechanical pumps. A condensing unit of 150 lbs. capacity is required with the ability to condense up to 50 lbs. of water per hour at the maximum. The maximum batch size is limited by the capacity of the condenser and would vary between about 200 lbs. for lean raw beef to 300 lbs. for pork chops or cooked meats.

Reliable estimates of the cost of the freeze-drying unit (including spiked plates) come to about $50,000. An estimate of the cost of drying by an independent consultant, assuming 200 days work of 24 hours a day, gave a figure of about 24¢ per lb. of water removed. This corresponds to a cost of about 16–17¢ to dry 1 lb. of raw beef or 13–14¢ to dry 1 lb. of pork. The cost of packaging in nitrogen using No. 2½ or No. 10 cans is an additional 20¢ per lb. of dry meat or 6–7¢ per lb. of raw meat equivalent. These figures allow for running costs, depreciation of the equipment over 10 years,, labour, overhead and profit.

The annual output of this equipment, operating as described, would be 30–40 tons of dehydrated meat, and it is unlikely that in peace time the Canadian Services could make use of this amount. For the project to be economically self-supporting other outlets would be essential.

Small scale trials in collaboration with Canadian Government Departments having personnel in the Arctic have indicated that organizations operating in Northern or isolated territories and relying on air transportation for supplies could find freeze-dried meats attractive and economical to use.

It seems probable that the requirements of Canadian Government personnel in the North would be sufficient to take up most of the residual production. Subsequent requirements of the mining and prospecting companies would be even larger, and may lead the way to commercial distribution.

SUMMARY

Several prepared baking mixes suitable for military use have been developed, comprising a yeast leavened bread mix requiring no bulk fermentation, a chemically leavened field bread mix and a cake-cookie-pudding mix.

Factors relating to the large scale production of dehydrated foods for the Canadian Armed Services have been studied. Hot-air dried cooked ground beef, which can be manufactured in Canada, has been shown to have a satisfactory storage life. An estimate of the cost of freeze-drying foodstuffs is given.

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Estimation of Vacuum in Unopened Containers

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IT IS A BASIC PRACTICE in the canning industry to endeavour to provide an adequate internal vacuum in canned foods. A good internal vacuum reduces the strain on the can during heat processing, holds the ends in a collapsed, concave position during subsequent storage, reduces the amount of headspace oxygen, and delays the appearance of hydrogen swelling by providing a reservoir for the accumulation of hydrogen.

Internal vacuum is generally measured by means of a puncture gauge, which, however, destroys the can. It is often necessary to estimate vacuum without destroying the can—for instance, when following the loss in vacuum in a series of cans over a period of storage, or when checking stacks to separate low and high vacuum cans. In the method known as the flip test, the can end moves as a diaphragm and is subjected to a gradually increasing external vacuum until the external pressure is low enough to make the can end "flip" from a concave to a convex position. The external vacuum at which the flip occurs is largely determined by the internal vacuum in the can. A number of instruments have been devised to estimate the flip vacuum in cans *(2, 4, 5, 8, 9)*.

Internal vacuum may also be estimated by instruments which depend on movements of the can end to a point short of flipping *(7, 11)*. An instrument of this type, recently designed in this laboratory by Lynch and Mitchell *(3)*, is considered to present worthwhile advantages over previous instruments. In particular it gives a direct steady reading of the flip [b] vacuum on a vacuum gauge.

Data on the relation between flip vacuum as measured with the instrument and internal can vacuum in a series of cans are presented. The performance of the instrument for the estimation of internal vacuum and internal vacuum loss on a series of cans packed with three test products has also been studied.

DESCRIPTION OF THE INSTRUMENT

In the present instrument, when the can end moves under the influence of an external vacuum it contacts the pin of an air valve which admits air so that a steady state is reached in which the external vacuum is balanced against the internal vacuum in the can.

Figure 1 shows a perspective view of the vacuum tester, and Figure 2 a sectional drawing of the instrument on a can. The instrument consists of a disc-shaped head (A) lined on the lower surface with a thin sheet of rubber. A metal guide ring (E) with an internal diameter of $3\frac{3}{32}$ in., an external diameter of $3\frac{29}{32}$ in. and $\frac{1}{16}$ in. thick is located centrally with respect to the valve, and fixed to the lining. This guide ring is suitable for 301 and 401 diameter cans and accurately locates the valve of the tester over the centre of the can end. Guide rings suitable for locating cans of other diameters may be substituted when necessary. Threaded through the centre of the head is a brass tube (H), the lower end of which is left unthreaded and passes through a standard type of oil seal (M) fitted in the head to ensure vacuum tightness. The tube at the lower end is threaded internally and accommodates an air valve (I) of the type used in automobile tyres, the pin of which projects below the tube. A knob (K) is fitted to the upper end of the tube, and rotation of this knob permits the height of the pin above the can end (B) to be adjusted. The knob rotates inside a circular graduated scale (L) which enables a particular setting of the valve pin to be roughly located. A vacuum take-off (G) fitted with a 1 mm. internal bore jet is provided through the side of the instrument. A second vacuum outlet leading to a Bourdon vacuum gauge (F) is also included.

To operate the instrument on a can with an internal vacuum, the height of the valve pin is adjusted to a point a little above the can end. A three-way tap

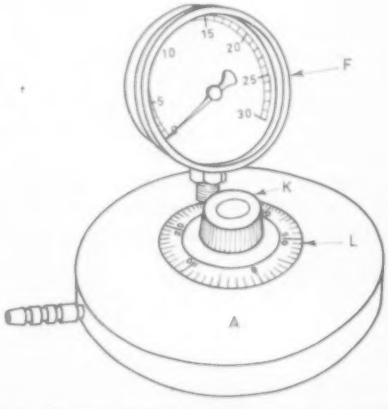

Figure 1. Vacuum tester for cans showing A, disc-shaped head; F, vacuum gauge; K, adjusting knob; and L, graduated scale.

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[b] Although the vacuum as measured with this instrument is strictly not the flip vacuum, for convenience in this discussion it will be referred to as the flip vacuum.

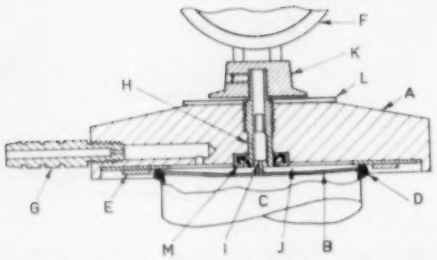

Figure 2. Cross-sectional view of vacuum tester in position on a can: A, disc-shaped head; B, can end; C, can body; D, can-end seam; E, guide ring; F, vacuum gauge; G, vacuum take-off; H, central tube; I, air valve; J, air space on top of can; K, adjusting knob; L, graduated scale; and M, vacuum seal.

in the vacuum line is then turned to connect the vacuum source and the small chamber (J) formed on top of the can. As this chamber is evacuated, the flexible end (B) of the can moves up and contacts the valve pin (I). Slight upward pressure on this spring-loaded pin opens the valve and admits air from the atmosphere through the central tube. The jet in the vacuum take-off limits the rate of removal of air by the vacuum pump, and the valve opening is automatically adjusted to admit air from the atmosphere at the same rate. The end point of the estimation is then given by a steady reading directly on the vacuum gauge which can be read at leisure.

With most canned foods, the vacuum readings are reproducible between separate readings made at any one time. With some solid packs such as meat loaf and cheese it may be necessary to move the can end with the instrument several times before successive readings become reproducible. These products commonly adhere to the internal surface of the can end and presumably restrict its movement.

Calibration. The approximate internal vacuum in cans may be estimated after calibrating the instrument on a can at atmospheric pressure; the can should be the same size and design as the cans to be tested. The valve pin is first adjusted to give a reading of 2–3 in. Hg on the can at atmospheric pressure, then transferred to the test can. The difference in the two readings then gives the approximate internal vacuum in the can. When periodic measurements on a set of cans over a period of storage are planned, it is desirable to have a more accurate method of adjustment and one which can be accurately reproduced on future occasions.

The calibration device, shown as a perspective view in Figure 3, provides an accurate reference point for the valve setting. It consists of a brass head (V) the upper side of which is shaped to reproduce the end seam (T) and concave shape of a 301 diameter can end. A micrometer (U), with the upper portion of the fixed G-shaped limb cut off, is firmly fixed to the lower side with the circular adjustable stem (W) passing through the centre. The micrometer stem passes through an oil seal fitted on the lower side of the head. The micrometer has a range of 0–1 in. adjustable to 0.0001 in. and is provided with a locknut.

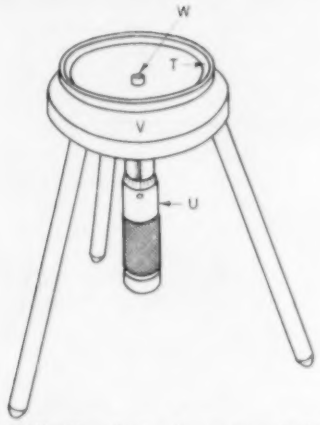

Figure 3. Calibration device for vacuum tester showing T, rim with dimensions similar to the end seam of a 301 diameter can end; U, micrometer; V, brass head; and W, micrometer stem.

To adjust the valve setting of the tester on the calibration device, the valve is first adjusted on a can at atmospheric pressure as previously described. The tester is then transferred to the calibration device with the micrometer stem out of contact with the valve pin. After applying a vacuum, the micrometer stem is raised until contact is made with the valve pin. This point will be indicated by a sudden fall in the reading recorded on the gauge. By adjustment of the micrometer, an arbitrary vacuum reading on the gauge is chosen and the micrometer and the gauge reading noted. All future adjustments are made to these values which can be accurately reproduced. In the present studies it was found convenient to use a micrometer setting of 0.5937 in. and a vacuum gauge reading of 10.0 in. Hg. This calibration permits the vacua in the cans being used in these experiments to be followed to a stage when the cans have lost all their vacuum. By decreasing the micrometer setting and therefore raising the height of the valve pin, the vacuum change can be followed to a stage where the can has an internal pressure and is about to flip. There is therefore a wide choice of micrometer settings available.

EXPERIMENTAL

The cans used for the test products were 301 x 411 cans made from one batch of Welsh hot-dipped tin plate specified as cold rolled, 1.25 lb./base box nominal coating weight, 90 lb. substance, and equivalent to American M.R. plate of temper T3. Cans for the calibration experiment were 301 x 411 cans made from two types of tin plate; the same batch of hot-dipped plate specified above and a second batch of American electrolytic tin plate specified as cold-rolled, type M.R., 1.00 lb./base box nominal coating weight, 95 lb. substance and temper T3.

Calibration experiment. The relation between internal vacuum in the cans and flip vacuum was determined using 8 hot-dipped and 8 electrolytic cans, selected at random from each batch. A short length of 5/32 in. internal diameter copper tubing was soldered over a hole pierced in the body wall of each can at a point close to the canmaker's end. Tubes were temporarily

sealed off, and the cans filled with boiled out water. The headspace was adjusted to give a final value of approximately 18 ml. and the cans closed. Using a glass tap connected to the copper tubes by a short length of rubber tubing, known levels of vacuum were drawn on these cans using a water pump and mercury manometer. Vacuum levels from 0 to 24 in. Hg in increments of 2 inches were drawn on each can, and the flip vacuum estimated with the tester. Care was taken to avoid loss of water from the cans during evacuation. Cans and vacuum levels were chosen for measurements in random order.

Test products. To study the performance of the tester both for the estimation of internal vacuum and internal vacuum loss over a period of storage at 86° F., test packs of 3 products were made in 301 x 411 hot-dipped tin-plate cans (Table 1). The products chosen were peaches, beetroot (acidified pack, pH 4.3) and boysenberries.

TABLE 1

Details of the test packs and plan of the examinations

Details	Peaches	Boysenberries	Beetroot
Lacquer	Plain cans	Acid-resisting	Acid-resisting
Number of cans packed	104	218	240
Initial vacuum range (in. Hg)	9.5–16.3	10.7–21.4	8.3–15.9
Examination intervals (weeks)	18	6	6
Storage period at 86° F. (weeks)	72	54	54
Number of cans examined			
After processing	12	18	18
At each examination	6	8	8
At end of experiment	36	....	....

Measurements on the cans removed for examination were made at room temperature. An estimation of the flip vacuum with the tester followed by an estimation of internal vacuum using a Campden manometer *(6)* was made on each can removed for examination. The puncture made by the needle of the manometer was then closed and a second flip vacuum estimation made. This second estimation represents a blank reading on the can at atmospheric pressure. The corrected flip vacuum for a particular can is then obtained by subtraction of the second or blank estimation from the initial flip reading.

RESULTS AND DISCUSSION

Calibration data. Individual analyses of the flip vacuum measurements showed that the data for each can were fitted well by a quadratic function of the true vacuum, but there were quite large differences from can to can in the coefficients of the quadratic function. Most of the can-to-can variation is associated with the differences that occur in the flip vacuum at zero can vacuum. Figure 4 shows the data and the calculated curves for the cans with the highest (a) and the lowest (c) flip vacuum at zero can vacuum and also the average curve (b). Although the relationship between the flip and the can vacuum is quadratic, the degree of curvature is not very great and for many purposes it would be adequate to approximate it by a straight line (d), which is also shown. The equation of the straight line (d) is

$$y = 5.4 + 0.766x \qquad (1)$$

An overall analysis of the calibration data is shown in Table 2. It should be noted that the error term in this table is not comparable in magnitude with the error term in subsequent tables. This analysis shows that any differences between the two types of tin plate are small and can be ignored in the present

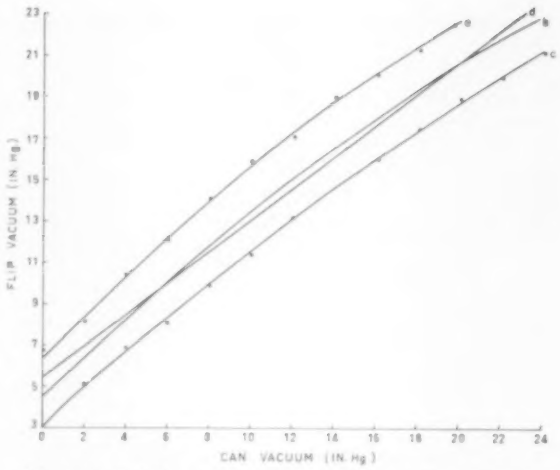

Figure 4. Relation between can vacuum and flip vacuum obtained from measurements on 16 cans at vacuum levels from 0 to 24 in. Hg. a = calculated curve for the can with the highest flip vacuum at zero can vacuum, b = average curve of 16 cans, c = calculated curve for the can with the lowest flip vacuum at zero can vacuum, and d = straight line relation of average values.

studies. Factors associated with the tin plate itself, such as temper and substance, do affect the readings obtained with instruments which rely on the actual flip of the can end. These factors result in a variation of the vacuum levels required to flip the cans with no internal vacuum, which makes the estimation of internal vacuum less reliable. With the present instrument, the setting for the end point detection can be chosen to correspond closely with the position of the can end with no vacuum, and errors associated with temper, substance and design of the can end are reduced. Cans made from the same type of tin plate and by the same canmaking machinery will show variation in the positions of the can ends without vacuum. This variation was found to be significant at the 0.1 per cent level in the present results. The analysis in Table 2 shows that the variability due to the tester itself measured as residual variation is small relative to the variability between cans. Because of this can-to-can variation, any calibration procedure for a tester of this general type should be based on a reasonable number of cans rather than on a single can.

Regarding the precision with which the internal vacuum of a can may be estimated using this instrument and an appropriate calibration curve previously constructed, two cases may be considered:

(i) when only a single flip vacuum reading is made, the standard deviation of the estimated can vacuum is approximately 1.3 in. Hg.

(ii) when two readings at different times are made, the standard deviation of the estimated change in the can vacuum between the two times is approximately 0.63 in. Hg.

These figures are derived from the 3 x 3 dispersion

TABLE 2
Analysis of variance of repeated flip vacuum measurements on sixteen cans[1]

Variation	Degrees of freedom	Mean squares
Between tin plates	1	46.3617
Average linear regression	1	6824.4754 ***
Average quadratic regression	1	40.1247 ***
Bet. tin plate, linear reg.	1	0.0935
Bet. tin plate, quad. reg.	1	0.6322
Bet. cans, within tin plate	14	12.4011 ***
Bet. linear regs., w'in tin plate	14	0.2776 ***
Bet. quad. regs., w'in tin plate	14	0.1007 *
Residual	160	0.0526
Total	207	

[1] Eight cans x 2 tin plates x 13 vacuum levels = 208; the vacuum levels being at equal intervals and the same for each can, orthogonal polynomials were used so that the linear and quadratic sums of squares are independent.
* Indicates significance at the 5% level.
*** Indicates significance at the 0.1% level.

matrix (not presented here) of the 3 coefficients of the quadratic functions fitted to the data for the individual cans, and equation 1.

The ratio of the change in flip vacuum to the change in can vacuum over the range of 0 to 24 in. Hg was found to be approximately 0.77 with the present tester. Flip vacuum readings obtained with this instrument should therefore be divided by the factor 0.77 to obtain the internal can vacuum. The ratio is not a direct 1 : 1 ratio because of the resilient nature of the sealing gasket. When the instrument is positioned on a can and a vacuum applied, the end seam of the can compresses the gasket material and the amount of compression increases as the vacuum increases. This results in a slight movement of the valve pin towards the can end. Some resiliency in the gasket material is necessary to form the seal, and the factor to be used for a particular instrument will be governed by the nature of this material. A variation in the diameter of the can end may also alter the ratio since the area of gasket material being compressed will be different for different end diameters. The instrument developed by The Metal Box Company, Ltd., *(11)* does not require a gasket and hence the vacuum may be estimated without the use of a conversion factor.

Test products. Data for the beetroot pack is shown in Figures 5 and 6. Figure 5 shows the flip vacuum for each can plotted against the true vacuum; Figure 6 shows the corrected flip vacuum for each can plotted against the true vacuum. Data for the peach and boysenberry packs gave similar graphs when plotted.

Regression analyses of the flip vacuum data (for the 3 test packs) are summarised in Table 3 in the form of analyses of variance. Residual variances for the beetroot and peaches are of the same order as the estimated value of 1.012 derived from the dispersion matrix calculated from the calibration data, but the boysenberries showed more variability. Each set of data was fitted by a linear function shown in Table 4, since only the peach pack gave significance at the 5% level in the test of the quadratic term. Further analysis indicates that these 3 regressions differ significantly from each other. Differences are mainly

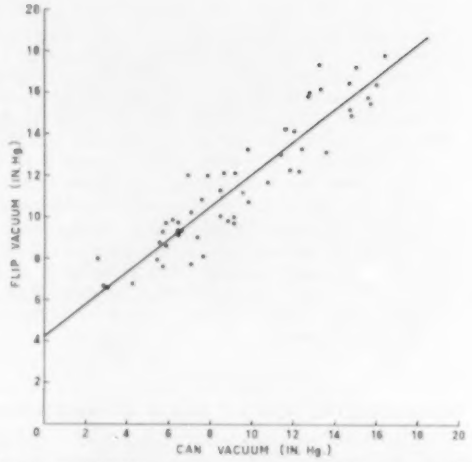

Figure 5. Relation of can vacuum to flip vacuum from a test pack of beetroot over a storage period of 54 weeks at 86° F.

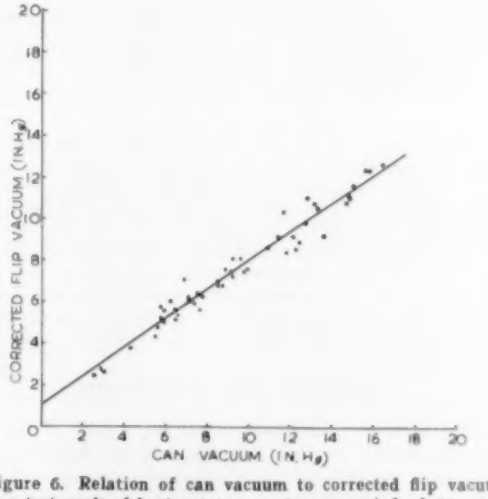

Figure 6. Relation of can vacuum to corrected flip vacuum from a test pack of beetroot over a storage period of 54 weeks at 86° F. The corrected flip vacuum refers to the difference between the flip vacuum estimations on each can before and after the can was punctured to release the internal vacuum.

due to differences in the constant term, the slopes being in reasonable agreement.

Regression analyses of the corrected flip data are shown in Table 5. These analyses show similar features to those noted from the analyses of the flip vacuum data; the residual variances are of the magnitude expected except for the boysenberries which show greater variability, and differences are present in the calculated straight lines due mainly to differences in the constant term (Table 4), the slopes being in fair agreement.

The straight lines which fit the corrected flip data (Table 4) did not pass through the origin as expected to within the order of accuracy of the experiment; those for the beetroot and boysenberries had greater

TABLE 3

Analyses of variance for flip vacuum data from the beetroot, boysenberry, and peach test packs

Variation	Beetroot		Boysenberries		Peaches	
	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares
Linear regression	1	436.9935 ***	1	1345.0726 ***	1	344.4163 ***
Quadratic regression	1	0.8922	1	6.8272	1	5.1129 *
Residual	49	1.4238	56	2.8171	57	0.9626
Total	51		58		59	

* Indicates significance at the 5% level.
*** Indicates significance at the 0.1% level.

TABLE 4

Relation of flip vacuum and corrected flip vacuum to can vacuum

Product	Estimated equation		Headspace (ml.)	
	Flip vacuum (y)	Corrected flip vacuum (z)	Range	Mean
Beetroot	$y = 4.3 + 0.786x$	$z = 1.0 + 0.707x$	21.4 – 28.7	24.1
Boysenberries	$y = 3.3 + 0.775x$	$z = 0.9 + 0.753x$	18.7 – 33.0	26.5
Peaches	$y = 2.9 + 0.884x$	$z = 0.2 + 0.813x$	31.7 – 38.6	35.7
Calibration cans	$y = 5.4 + 0.776x$	$z = 0.766x$	12.7 – 24.6	17.8

TABLE 5

Analyses of variance for corrected flip vacuum data from the beetroot, boysenberry, and peach test packs

Variation	Beetroot		Boysenberries		Peaches	
	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares	Degrees of freedom	Mean squares
Linear regression	1	353.4148***	1	1268.7432***	1	220.1340***
Quadratic regression	1	0.0216	1	0.0835	1	1.7925*
Residual	49	0.2843	56	0.5088	52	0.2689
Total	51		58		54	

* Indicates significance at the 5% level.
*** Indicates significance at the 0.1% level.

intercepts than that for the peaches. Similarly, the linear functions for the flip vacuum data showed differences in the constant term, the cans used for the calibration having the largest constant term followed by beetroot, boysenberries and peaches in that order. An examination of Table 4 shows evidence of a relation between the average headspace of the four sets of cans and the constant term, an increase in the headspace resulting in a decrease in the magnitude of the constant term. The headspace of filled cans is known to affect flip vacuum readings obtained with instruments which rely on the actual flip of the can end *(10)*. The expansion of the gas in the headspace offers a resistance to the upward movement of the can end, and small headspaces increase the vacuum required to flip the end. Although the final position of a can end at the end point of a determination using the present instrument is below that at which the end flips, the total movement of the can end is still sufficient to be affected by different headspaces. For this reason, the headspace levels of test packs made for vacuum loss estimations should be controlled, and the calibration of the instrument made on cans with a similar headspace.

Advantages of the present instruments. The instrument described has several important advantages over previous instruments.

1. With instruments which rely on the flip movement of the can end, it is not possible to obtain readings on cans with a high internal vacuum particularly if the end diameter of the cans is small. With 301 diameter ends for instance, the flip vacuum may be 9 to 14 in. Hg higher than the true internal vacuum *(4)*. When such cans have vacua in the region of 20 in. Hg, it is unlikely that the ends will flip under the influence of an external vacuum. Cans with end diameters smaller than 301 and most metal closures for glass containers are unsuitable for flip vacuum studies with these instruments whereas testers which depend on a small movement of the can end may be used.

2. The flip movement of a can end is dependent on several factors associated with the can, and because of this, methods based on this movement are subject to several inaccuracies *(1)*. The temper and substance of the tin plate, the number of expansion rings in the can end, the diameter of the end and the headspace of the filled can are among these factors. Testers dependent on a smaller movement of the can end to a position close to that of the end when the can has no internal vacuum would be expected to reduce considerably these sources of error.

3. Finally, the instrument described has the additional advantage over previous instruments that the end-point of each estimation is given by a steady, direct reading on the vacuum gauge which can be read accurately and at leisure. With previous testers the vacuum gauge must be read while the needle is moving at a particular instant indicated by the sound of the flip *(2, 5, 8, 9)*, the glowing of a lamp *(4)*, the

ringing of a bell *(7)* or the position of a pointer on a second gauge *(11)*. Moreover, the control valve in the vacuum line must be carefully controlled to give a slow movement of the vacuum gauge pointer and this is both tedious and time consuming.

SUMMARY

An instrument for the estimation of internal vacuum in sealed containers has been described. The instrument is easily constructed and more convenient to use than existing instruments of this general type.

The performance of the instrument in service was assessed on a series of test packs in 301 x 411 cans, and the results analysed statistically. Results showed that when used in conjunction with a calibration curve, the internal vacuum of the cans could be estimated with a standard deviation of 1.3 in. Hg.

Measurements on individual cans over a period of time showed that the changes in flip vacuum were very nearly proportional to the changes in internal vacuum over the range 0-24 in. Hg, and for practical purposes a linear relation may be used. The standard deviation in these estimations was 0.6 in. Hg.

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Development and Evaluation of Potato Chip Bars [a,b]

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ALTHOUGH POTATO CHIPS are well liked by personnel in the Armed Forces, the Quartermaster Corps has been unable to supply them in their usual form as a ration because of the excessive space requirement in packaging and the lack of storage stability. In order to circumvent these obstacles, the Eastern Regional Research Laboratory and the Quartermaster Food and Container Institute for the Armed Forces undertook in 1951 to develop compressed potato chip bars. The purpose of this work was not only to develop bars that might be used as a military ration, but also a product that should be useful as a concentrated foodstuff for stockpiling in protection against disasters and as a civilian snack.

It was found at the outset that chip crumbs could be pressed at ordinary temperature into bars that occupy a volume only about one-twentieth of the original packaging volume of the chips. The bars were self supporting, although it was evident that certain conditions, then undefined, had to be met to prevent excessive crumbling. As it developed, these conditions could be alleviated by selection of the proper type of fat for frying the chips and determination of the order of particle size to which the chips should be reduced before pressing. Details such as the amount of pressure, mode of application, and application time had to be established for obtaining best results in pressing. In addition it was found that a chilling treatment following pressing was of value in firming the bars before wrapping.

It is required by the Quartermaster Corps that ration bars have: 1) acceptable flavor and texture; 2) adequate stability (should remain palatable for at least 6 months during storage at 100° F.); 3) high calorie density, preferably 5 calories or more per gram; and 4) suitable physical characteristics to permit commercial production without undue difficulties. It was immediately recognized that potato chip bars meet the first and third requirements. Chips furnish on the average 5.5 calories per gram. They comprise a concentrated, nutritive foodstuff, containing normally only 2 to 2½% moisture. They contain 35 to 45% fat. The potato solids are made up of 65 to 75% starch, nearly 10% nitrogenous substances, and considerable quantities of inorganic constituents rich in potassium and phosphorus. Tests described in this article proved that chip bars remain palatable and are quite stable in composition during long storage. Limited experience in semi-commercial production of chip bars has indicated that this item should not be difficult to produce in regular commercial operations.

PRELIMINARY EXPERIMENTS

In the initial experiments, the chips were crushed by mild mechanical treatment such as by a wooden roller. Other methods included forcing them through the coarse colander of a Hobart Mixer (Model N-50)[e] by means of the ceramic roller. For most laboratory experiments, though, the chips were crushed by the flat beater attachment of a Hobart Mixer, moving in planetary motion in the bowl at slow speed. The chips were disintegrated to about ⅛ to ¼ inch on a side. Breakage to increasingly smaller particle size eventually leads to material of the consistency of peanut butter. Too large particle size results in poor binding.

Cylindrical molds were used in the laboratory for pressing bars in Carver and in Elmes manually-operated, hydraulic presses. With these presses, the pressure was built up gradually to a maximum, with a total pressing interval of 2 minutes.

Oil loss. The loss of oil during pressing is influenced by several factors: 1) softening point of the fat in which the chips are fried; 2) fat content of the chips; 3) maximum pressure applied in pressing; and 4) manner in which the pressure is applied and time that it is maintained. Since it is desirable to retain the original fat content of chips in the bar, it is important to employ conditions that will minimize fat loss. Table 1 presents laboratory data on the oil loss obtained with 2 samples of chips from the same manufacturer. Crushed chips were compressed in a cylindrical mold 1-$\frac{5}{32}$ inches in diameter to the specified maximum pressures. Chips had been fried in peanut oil. Fat contents of the 2 samples were significantly different, a fact which is reflected by the relative amounts of oil expressed. Loss of fat was nil with one sample and almost negligible with the other at 500 p.s.i. Oil loss increased rather regularly as the maximum pressure was increased to 7,000 p.s.i.

Volume reduction. The volume of a compressed potato chip bar is dependent on the maximum pressure applied during pressing. In the range of 3,000 to 4,000 p.s.i., the volume re-

[a] This paper reports research, part of which was conducted at the Quartermaster Food and Container Institute for the Armed Forces, and has been approved for publication. The views or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or endorsements of the Department of Defense or the Department of Agriculture.

[b] Presented at the Thirteenth Annual Meeting of the Institute of Food Technologists, Boston, Mass., June 24, 1953.

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[e] Commercial equipment and products referred to in this article are not recommended or endorsed by the U. S. Departments of Agriculture or Defense over similar types of other manufacture.

TABLE 1

Oil loss on pressing 20 g. samples of crushed chips

Maximum pressure	Oil expressed from 37%-fat chips	Oil expressed from 42%-fat chips
p.s.i.	*g.*	*g.*
500	0.7	None
1,000	1.3	2.3
2,000	2.1	3.1
3,000	2.8	3.8
4,000	3.3	4.4
5,000	3.7	5.5
6,000	4.0	5.8
7,000	4.3	6.0

duction is about 20 to 1. This great volume reduction is not primarily due to compression of chip tissue, but arises from the fact that chips in their ordinary form occupy large packaging space. The volume reductions obtained on pressing, in the laboratory, chips containing 35% hydrogenated vegetable shortening are given in Table 2. Part of the volume reduction, of course, is due to the loss of expressed oil, values for which are also given. Direct comparison cannot be made of the oil loss data of Tables 1 and 2, because different lots of chips were used and pressing details were not the same.

TABLE 2

Volume reduction on pressing 20 g. of chips (17.4 cu. in. packaging volume) in cylindrical mold

Pressure	Oil loss	Volume
p.s.i.	*g.*	*cu in.*
500	0.5	1.12
1,000	1.2	1.09
1,500	1.9	1.04
2,000	2.8	0.97
2,500	3.1	0.93
3,000	3.7	0.89
3,500	4.1	0.86
4,000	4.1	0.85
5,000	4.5	0.84
6,000	4.5	0.83

IMPROVEMENT OF BINDING AND FIRMNESS

There are indications that chips fried in hydrogenated vegetable shortening give firmer, better bound bars than those fried in liquid vegetable oils. Some feel, however, that ordinary hydrogenated shortening does not give bars that possess adequate firmness to resist impact and crushing without crumbling. Binders such as dextrin, casein, and dehydrated corn sirup were mixed with crushed chips before pressing. Water had to be added to bring out the adhesive properties of these substances. It was later found in laboratory experiments that increase in moisture content alone without addition of binder apparently helped by utilizing the adhesive properties of the starch and dextrin naturally occurring in chips. Experience proved, though, as discussed below in connection with the first large-scale evaluation of the chip bar, that increased moisture content results in lower storage stability and loss of characteristic crispness.

Coating of the bars with tasteless film formers applied from aqueous solution was tried without much success in improving the binding. Pectin, for example, was unsatisfactory in that the film peeled from the surface as it dried.

Use of hard shortenings in frying chips has been considered as a means for increasing the firmness of bars. Vegetable shortenings hydrogenated to such an extent that they are hard at ordinary temperature provided bars that were deemed too hard. A blend of soft and hard shortenings or use of a shortening of intermediate hardness has given bars of suitable hardness in laboratory tests.

Hard shortenings, however, have not been used to any great extent by industry in frying. Manufacturers thus have little information on their performance in this respect. Hence, the use of hard shortenings in any large-scale trial should come only after thorough testing of small lots of chip bars in the laboratory. These shortenings appear to be exceedingly stable against oxidative deterioration. They reportedly hydrolyze more readily than soft shortenings, but the low moisture content in chip bars should prevent pronounced hydrolysis.

PREPARATION OF CHIP BARS FOR STORAGE TESTS

In order to obtain more data on the processing of chip bars and on the storage stability of the product, a special lot of chips was produced with commercial equipment. Hydrogenated vegetable shortening was used by the processor in the frying. To the shortenings, was added 0.13% of a commercial antioxidant. This preparation consisted of 20% butyl hydroxyanisole, 6% propyl gallate, 4% citric acid, and 70% propylene glycol. Operating conditions in the continuous fryer were typical, with the fat at 375° F. at the front of the oil bath where the slices entered and 300° at the rear, where they were removed 3 to 4 minutes later.

Crushing. Crushing was carried out to the desired particle size by use of an intermediate-size Hobart mixer equipped with a wire loop attachment.

Moisture addition. The moisture content of portions of the special lot of chips was increased to approximately double and triple the original value in order to evaluate further the addition of moisture as an aid to binding. Weighed amounts of water were sprayed in while stirring the material in the 20-gallon bowl of a Hobart mixer with the dough hook attached. After standing overnight in sealed containers, the crushed chips in each lot had uniform moisture distribution.

Pressing. A Denison "Hydroilic Multipress" was used at the Quartermaster Food and Container Institute in pressing bars 3 inches x 1 inch x ⅝ inch. An acceptable bar was produced by applying a single stroke of the punch (entering the die from above) at 3,000 p.s.i. for about 4 seconds. The ejector, on moving from the bottom to the top of the die cavity, removed the bars without damaging them perceptibly. Although the shortening became nearly fluid during the pressing, no oil was expressed as had been the case with laboratory presses. Perhaps the time interval during compression is largely responsible for this difference.

Bars were chilled in a freezer to firm them before wrapping in thin aluminum foil. They were wrapped by hand, although it was later demonstrated that they could be machine-wrapped.

A total of more than 1,000 bars were prepared from crushed chips at approximately 2, 4, and 6% moisture; bars at these 3 moisture levels were coded "A", "B", and "C", respectively. The wrapped bars were canned in nitrogen and in air. The cans were stored at 40°, 70°, and 100° F. Chip bars were also sealed in envelopes (air pack), made of kraft paper laminated with an inner, plastic film. It was later found that this type of packaging did not give the required protection for high-temperature storage.

In addition, a smaller number of bars from regular commercial chips fried in 80% corn oil-20% hydrogenated vegetable shortening with antioxidant, were wrapped, canned (some in air and some in nitrogen), and placed in storage at the three temperatures. Bars prepared from chips fried in the corn oil-shortening mixture were designated "D".

Chemical determinations were made on the bars one month after their preparation. Two cans were selected from each moisture level group. Since the values obtained in these duplicate samples agreed well, they are averaged together in the data given in Table 3. The percentage fat decreased, of course, as more moisture was incorporated. The free-fatty acid and iodine number values were higher for "D", the only lot containing corn oil.

INITIAL TASTE EVALUATION STUDY

Shortly after the bars were prepared, samples of the 4 different formulas (A, B, C, and D of Table 3) were submitted to a panel of 20 trained judges at the

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TABLE 3

Analytical and fat characterization data[1] on potato chip bars

	A	B	C	D
Moisture, %	2.3	3.9	5.5	2.2
Ash, %	4.5	4.6	4.6	4.2
Fat, %	37.3	35.8	35.1	37.9
Protein (N x 6.25), %	4.0	4.0	3.9	4.0
Cl, as NaCl, %	2.7	2.8	2.7	2.3
Perox. Val.	3.7	3.3	2.8	3.3
Free fatty acid, %	0.07	0.09	0.10	0.23
Iodine No.	66.1	66.5	66.6	79.1

[1] All determinations by procedures in *Official Methods of Analysis of the Association of Official Agricultural Chemists*, Seventh Ed., (1950), except peroxide value, by method in Jacobs, *Chemical Analysis of Foods and Food Products*, p. 434 (1938).

Quartermaster Food and Container Institute. Judges rated the samples on a 9-point hedonic scale (Table 4). This scale permitted 4 degrees of *dislike*, a neutral position, and 4 degrees of *like* in the following descriptive terms, valued in the order given as 1 to 9: *dislike extremely, dislike very much, dislike moderately, dislike slightly, neither dislike nor like, like slightly, like moderately, like very much*, and *like extremely*. Judges were instructed to reflect their general acceptance of the item for possible use in the Army's "Assault Ration" as well as to rank the different samples in the order of preference.

Some tasters thought that the bars whose scores are given in Table 4 were too salty and that B and C were "rancid." The latter effect is perhaps due to loss of characteristic crispness accompanying the unnaturally high moisture contents. Tasters had a preference for the bars made from commercial chips (lot D) over those from the special chips fried in hydrogenated vegetable shortening, although this preference

TABLE 4

Taste evaluation of freshly-prepared chip bars

Sample	Score	% Scoring in dislike range
A	6.2	25
B	5.8	35
C	5.8	40
D	6.5	20

over lot A was slight. In general, the degree of acceptance for a product of this type was considered as quite satisfactory.

THREE MONTHS' STORAGE TESTS

Samples of the 4 different formulas of chip bars were again given to the same panel after the bars had been stored 3 months at 40°, 70°, and 100° F. Results are given in Table 5. Since the difference between the air and nitrogen packs was insignificant during the early phase of the storage, values for the 2 packs are averaged together in this table.

The scores of 40°- and 70°-stored samples were nearly the same at the end of 3 months. At 100° F. some decline was in evidence, particularly with the C and D formulations.

SIX MONTHS' STORAGE EVALUATION

After 6 months' storage, the bars were tested by

TABLE 5

Taste scores and percentage dislike[1] of chip bars after 3 months' storage

Temperature	A	B	C	D
°F.				
40	6.3(20)	6.7(10)	6.1(34)	6.9(50)
70	6.5(15)	6.3(20)	6.0(41)	6.8(17)
100	6.1(20)	6.1(30)	5.0(65)	5.9(30)

[1] Percentage of tasters scoring in dislike range given in parentheses following taste score.

the 20 tasters who had previously rated them. Formula D was dropped from consideration, since these samples had developed an off-flavor. Even bars of this lot that had been canned in nitrogen exhibited appreciable browning. Scores for the 6 months' test are given in Table 6, with data on the percentage dislike.

Except for the 100° F. nitrogen pack of formulas A and B, the scores regularly diminished from A to C accompanying higher moisture content. Nitrogen-pack samples received slightly higher scores than air pack. There was little difference between the 40° and 70° samples. The acceptability score of the 40° samples after 6 months was actually above the original.

TABLE 6

Taste scores and percentage dislike[1] of chip bars after six months' storage

Temperature	Pack	Score		
		A	B	C
°F.				
40	N_2	7.15(5)	7.0(5)	6.5(15)
40	Air	6.55(25)	6.35(25)	6.3(15)
70	N_2	6.8(20)	6.62(12)	5.8(35)
70	Air	7.05(5)	6.65(20)	5.65(45)
100	N_2	5.95(30)	6.3(25)	4.9(60)
100	Air	5.6(40)	5.35(45)	4.5(75)

[1] Percentage of tasters scoring in dislike range given in parentheses following taste score.

This is probably due to a better attitude of the tasters toward this product as they became accustomed to it. It also indicates little flavor change.

Peroxide value determinations were made on the chip bars and gaseous contents of the containers analyzed after the samples had been stored for 6 months. Results in the main were about the same as in the original analyses. However, as shown in Table 7, considerable oxygen uptake (indicative of oxidative rancidity development in the fat) occurred in the air packs at 100° F. This suggests that nitrogen packing should be used for high temperature storage.

EVALUATION AFTER ONE YEAR'S STORAGE

Sensory evaluation of the chip bars after one year's storage resulted in scores high enough to indicate that the product should be acceptable. Bars that had been canned in nitrogen and stored at 70° F. received about the same rating as at the time they entered storage. The air pack stored at 70° was still palatable, although less so than the nitrogen pack. Storage at 100° F. resulted in definitely lower scores than at 70° F. Table 8 gives the ratings scored by the judges.

TABLE 7

Composition of head space after 6 months' storage of canned chip bars at different temperatures. Air and nitrogen packs

Temperature °F.	40		70		100	
Pack	Air	N_2	Air	N_2	Air	N_2
Formula A						
% CO_2	0.7	0.6	1.2	0.9	3.1	1.5
% O_2	19.2	1.4	17.1	0.9	12.0	0.3
Formula B						
% CO_2	1.2	0.9	2.2	1.3	4.1	1.9
% O_2	17.4	1.5	17.8	1.7	15.5	0.3
Formula C						
% CO_2	1.2	1.3	2.7	0.8	6.9	1.5
% O_2	17.4	1.5	15.2	0.6	8.5	0.3

Only the A group, containing the least moisture, was examined chemically after one year's storage because the others were considered to be beyond the range of normal acceptability. Samples from 100° F. storage were selected for examination, since chemical changes would be expected to be most pronounced at the high temperature. The CO_2 content in the head space of the cans was of the same order as at the six months' sampling period. The O_2 content in the head space, however, had fallen after a year to about 3% in the air pack and to zero in the nitrogen pack. The air-pack cans were under 3½ to 4 inches of vacuum, showing that changes in high-temperature storage involved predominantly absorption rather than evolution of gas.

TABLE 8

Taste evaluation of chip bars (2.3% moisture) after one year's storage

Temperature °F.	Pack	Score	% of tasters scoring 5 and below
70	N_2	6.50	15
70	Air	5.75	45
100	N_2	5.15	65
100	Air	4.9	65

The free fatty acid content of the low-moisture chip bars remained essentially unchanged during the year's storage, with no appreciable hydrolysis of fat in evidence. The peroxide value of the bars packed in air, however, increased from about 3 to 20, indicative of oxidative deterioration in the fat.

POSSIBILITIES IN THE CIVILIAN MARKET

Chip bars have also been evaluated by an untrained, consumer-type taste panel of 40 persons at the Chicago Quartermaster Corps Depot. Bars produced from a second lot of chips fried in hydrogenated vegetable shortening containing antioxidant were used in this test. Antioxidant salt (The Griffith Laboratories, Inc., "GS-245" product) was employed in seasoning the chips. Since the first lot of chip bars was considered too salty, the NaCl content was reduced from 2.6 to 1.3% for the second lot. Although some complained of low salt content in this second lot, only 15% of the tasters disliked the bars. The degrees, which corresponded well with the score premean score for taste was 6.2 on a hedonic scale of 9 viously accorded the product by the trained panel of 20 persons. Some tasters objected to greasiness and lack of flavor, both of which could be improved for a civilian-type bar by using vegetable oils, e.g., corn or peanut, for part of the frying-fat requirement and by use of suitable flavor adjunct.

In addition to the evaluation by a consumer-type panel, samples of potato chip bars have been given to a fairly large number of individuals at the Eastern Regional Research Laboratory and elsewhere for tasting. The reaction on the whole has been satisfactory, particularly to bars containing some vegetable oil. Since the civilian-type bar would not have to remain stable over a long period, the use of a blend of vegetable oil and shortening in frying the chips should give a product of satisfactory shelf life.

SUMMARY AND CONCLUSIONS

Potato chips crushed to ⅛ to ¼ inch on a side and compressed at 500 to 3,000 p.s.i. give self supporting bars in which the characteristic crunchy texture of the original chips is preserved. The oil loss is slight or nil if the chips are fried in hydrogenated shortening and compressed in an automatic press under optimum conditions.

Sensory evaluation of the chip bars after one year's storage resulted in scores high enough to indicate acceptability as a ration component for the armed forces. Canned bars stored at 40° and 70° F. for a year were still palatable, while those stored at 100° F. were definitely lower in degree of acceptability. During the year's storage, the free fatty acid content of the bars remained substantially unchanged. The peroxide value of the air-pack product, however, increased appreciably during 100° F. storage. The oxygen content in the head space of the air-filled cans decreased decidedly during high temperature storage, indicating that a nitrogen pack should be used to prevent oxidative deterioration over a long keeping period.

Evaluation by a consumer-type panel indicated that potato chip bars might also have possibilities as a civilian food product. With the less rigorous stability requirements of a civilian product, it should be feasible to fry the chips in a vegetable oil-shortening blend, which appears to make the flavor of the bar more attractive.

Acknowledgment

The authors wish to acknowledge the assistance of the following persons: Dr. P. A. Wells, Director of the Eastern Utilization Research and Development Division, in suggesting the investigation; Dr. Ora Smith, Research Director of the National Potato Chip Institute, in planning the early phases of the work; and Ann S. Hunter and James Siciliano, Eastern Regional Research Laboratory, in carrying out certain laboratory experiments.

A Comparison of an Objective and Subjective Measurement of Beef Tenderness[a]

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(Manuscript received March 19, 1958)

TENDERNESS OF COOKED BEEF is one of the most important factors influencing acceptance. Of the several objective methods reviewed by Bate-Smith *(1)* and Schultz *(10)* for determining tenderness of meat, the Warner-Bratzler shear has been used almost exclusively in the United States. The difficulties encountered in measuring tenderness with this instrument are well known. Several investigators *(2, 5, 7, 9)* report a high correlation between "shear" values and judging panel scores, whereas others *(3, 6)* present evidence indicating that the apparatus should be redesigned or modified to increase its sensitivity and reliability.

The results of Miyada and Tappel *(8)* in using a household food grinder, which they found required no definite-sized sample or alignment of sample, to measure texture of beef offered encouragement for using the food grinder in large scale studies. Therefore, as part of studies on consumer acceptance of beef at Oregon State College, the household food grinder was used as an objective measurement of tenderness to compare with the opinion of the trained taste panel.

This paper reports a two-year comparison of the food grinder measurements of tenderness of rib roasts with the scores of trained judges.

EXPERIMENTAL

First year. Fifty-nine standing rib roasts consisting of the 10th and 11th ribs and ranging in U.S.D.A. grades from prime to utility were used in this test. Roasts were purchased 5 days after slaughter from a meat packing plant (over a 6-weeks period) and held in a 34° F. cooler for an additional 5 days. Weights of the roasts ranged from 3.56 to 5.90 pounds with the average being 4.70 pounds. Roasts were cooked in a gas oven at 325° F. in uncovered pans to an internal temperature of 170° F. as measured by copper-constantan thermocouples attached to a recording potentiometer. The ribeye muscle *(longissimus dorsi)* was cut from each roast and sliced across the grain. The center slices were served immediately on warm porcelain plates to the taste panel. A 100–200 g. sample was removed for objective testing and immediately wrapped in heavy duty aluminum foil to minimize heat and evaporation losses.

For objective measurements of tenderness the Hamilton-Beach food mixer (Model H)[b] was fitted with the grinder attachment and plate containing 36 holes 5 mm. in diameter. The motor was wired in series to an A.C. ammeter and operated at a constant voltage of 115 volts. Samples of warm meat were weighed after being cut into cubes roughly ½ inch in each dimension. One cube was dropped into the grinder for each turn of the feeding screw. The ampere readings were recorded at 5-second intervals and subsequent energy plots were made as described by Miyada and Tappel *(8)*. Two technicians were used to feed the machine and record the amperage, but a recording ammeter can replace one technician. Most of the samples weighed 110 to 140 g., but several weighed more than 200 g. These latter were divided in two; this permitted a crude measure of the reproducibility of the method under operating conditions.

Tenderness was measured subjectively by a panel of 11 judges. The judges had all participated in 12 preliminary training sessions during which four samples of meat of varying degrees of tenderness were scored. After scoring at each session a discussion was held to arrive at a general panel agreement of the degree of tenderness which best corresponded to the descriptive word scale on the ballot. The descriptive word scale range was from 7, *very tender*, to 1, *very tough*.

Meat samples were served to the judges, who were instructed to chew the sample in a normal manner and record their opinion on the ballot. During the scoring of the experimental samples, no discussion was allowed.

Because of the limitations of the preparation facilities it was necessary to serve the different samples at intervals throughout the day, but all the grinding measurements were made at one time. That is, samples of beef were tasted at 10, 1, and 3 o'clock but grinding was done only at 3 o'clock. Thus there may have been as much as a 5 hour delay between preparing and grinding.

Second year. Eighty-six standing rib roasts (10th and 11th ribs) were cut from carcasses of experimental animals selected from a feeding trial to be reported elsewhere. The U. S. Department of Agriculture grades as assigned to the different carcasses by experienced graders were *standard*, *good*, and *choice*. These roasts were smaller than those for the first year, the average weight being 3.84 pounds while the range was 2.92 to 4.66 pounds. The cooking and tenderness methods were the same as described above except that the roasts were cooked to an internal temperature of 160° F. and 12 judges served on the taste panel. The samples were ground immediately after being cooked.

RESULTS AND DISCUSSION

Table 1 compares the energy consumption, expressed as joules per gram, of some duplicate portions of the same sample cut in half and then cubed. While the average coefficient of variation for the various samples, 5.0%, is larger than the 2.11% reported by Miyada and Tappel for parawax, it appears low enough to justify using the method under what are probably extreme conditions—a large number of different samples which must be evaluated in a short time.

One factor which cannot be controlled adequately by hand-cutting during routine operations is the size of cubes into which the sample is cut. A ⅝ inch cube has approximately twice the volume of a ½ inch cube,

[a] Technical Paper No. 1107, Oregon Agricultural Experiment Station.

[b] The brand name is used for identification only and does not indicate endorsement by the authors or Oregon State College nor imply superiority over other grinders in the same category.

TABLE 1

Energy consumption by duplicate samples of longissimus dorsi

Sample number	Sample weight	Joules	Joules per gram
	(grams)		
1 A	137	1715	12.5
B	136	2030	14.9
2 A	109	1210	11.1
B	150	1555	10.4
3 A	109	1230	11.3
B	111	1250	11.3
4 A	100	1615	16.2
B	94	1480	15.7
5 A	101	1480	14.7
B	97	1560	16.1

and hand-cutting the sample into smaller cubes could be construed as performing some of the grinder's work and hence lowering its energy consumption. It is interesting, therefore, that samples 4A and B consisted of 54 and 52 cubes, respectively, or average weights per cube of 1.85 and 1.81 g. Similarly, samples 5A and B consisted of 43 and 45 cubes, respectively, or average weights per cube of 2.35 and 2.16 g. These indicate a much smaller error in cutting the sample than might be assumed. Also, sample 5B, although having the smaller cubes and, therefore, presumably the one for which part of the grinder's work had already been done, showed the higher energy consumption per gram. No generalization is valid on the basis of this single sample, but the results suggest that small differences in cube size are not important in practice and are not the major cause of the difference in energy consumption between duplicate samples. However, a mechanical slicer or cuber would help to maintain uniformity of cube size and possibly speed up the operation.

Table 2 compares the energy consumption per gram of some representative beef samples with the taste panel's judgment of tenderness. A low energy value or a high panel score indicates a very tender sample. The data for all samples show that the energy consumption is well related to panel measurements of tenderness as revealed by correlation coefficients of $-.59$ and $-.60$ with 57 and 84 degrees of freedom (for 59 and 86 samples) for the first and second year, respectively. These are both significant at the 1% probability level. Agreement within the taste panel was not perfect; adjusting for this variation yielded a correlation coefficient of $-.64$ for the first year's study. These correlations, while statistically significant, indicate, however, that only about one-third of the variations in tenderness found by the taste panel can be explained by the grinder method. This suggests that further improvements should be made in the grinder method before it can be considered entirely satisfactory for evaluating the tenderness of meat samples. Such improvements may lie in the use of a recording ammeter and a mechanical cuber.

TABLE 2

Tenderness values of longissimus dorsi

Year	Sample number	Joules/ gram	Panel average
1956	11	9.0	5.6
1956	12	15.3	4.8
1956	13	19.3	4.3
1956	14	21.8	3.8
1957	21	8.2	5.3
1957	22	12.7	4.8
1957	23	17.9	4.3
1957	24	24.2	3.5
1957	25	37.2	3.1

Table 3 shows how the interval between tasting and grinding the sample affects the correlation. The data indicate the desirability of grinding and tasting as soon as the sample has been prepared, but even with a 5 hour delay between tasting and grinding significant correlations can be obtained.

TABLE 3

Effect upon correlation of interval between tasting and grinding

Interval	Number of samples	Correlation coefficient
(hours)		
0	17	$-.660^{**}$
2	18	$-.583^{**}$
5	24	$-.534^{**}$

** Significant at .01 level.

In view of these correlations, it should be noted that Hanning *et al. (4)*, using cold meat the day after cooking, recently reported that the food grinder method was not sensitive enough to indicate statistical significance in tenderness of veal loin chops from calves raised by different feeding methods, whereas Warner-Bratzler shear force values and two methods of evaluation of tenderness by judging panel showed statistically significant differences of the same trend between feeding methods.

SUMMARY

Tenderness of samples from the *longissimus dorsi* muscle of standing rib roasts was measured subjectively by a trained taste panel and compared with the energy required to grind samples from the same muscle in a grinder attachment on a home food mixer. Correlation coefficients of $-.59$ and $-.60$ were obtained between the objective and subjective tenderness measurements. The highest correlation coefficients were obtained when the meat was ground and tasted immediately after preparation. Duplicate samples showed about a 10% variation in the energy required.

The grinder method, plotted and interpreted as by Miyada and Tappel *(8)*, suggests an inexpensive method for evaluating the tenderness of meat samples by which many samples can be processed in a short time.

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Nutritional Study of Instant Coffee Powder*

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(Manuscript received April 15, 1958)

In view of the widespread consumption of coffee beverage, it is of interest to consider its effects from a nutritional standpoint. In this regard little was known before the discovery of substantial amounts of niacin in roasted coffee *(15, 16)*. Recently the biological activity of the niacin in roasted coffee was confirmed by rat assay, a survey of the niacin content of commercial roasted coffees was made, and certain other nutrients in green and roasted coffees were measured *(17)*. In this report, similar studies on instant coffee powder are discussed.

MATERIALS AND METHODS

Instant coffee powder samples. The bioassay was performed on one of the more popular retail brands of instant coffee powder. For the survey of niacin in instant coffee powders, samples of other brands were purchasd on the retail market in Madison, Wisconsin, in January, 1957. Instant coffee powders contain approximately 2.5% moisture.

Analytical procedures. Microbiological assays were employed for niacin *(8)*, choline *(6)*, pantothenic acid *(13)*, folic acid *(1)*, citrovorum factor *(12)*, vitamin B_6 *(4)*, vitamin B_{12} *(9)* and riboflavin *(10)*. The thiochrome method *(3)* was applied in the case of thiamine. Standardized procedures were used for determining sodium *(5)*, fluorine *(2)*, total iron *(11)* and calcium *(7)*.

Bioassay. The basal ration consisted of 7% casein, 14% zein, 74% sucrose and 0.55% L-lysine, plus essential minerals and vitamins, except for niacin *(14)*. Weanling male rats (Sprague-Dawley, Madison, Wisconsin) were placed on experiment in individual cages. Ten rats were used per group. The standard nicotinamide and instant coffee powder were mixed intimately with the basal rations. At comparable growth rates, feed efficiency was the same on either supplement.

RESULTS AND DISCUSSION

Growth data of the bioassay are given in Table 1. At the lower supplement level the niacin value obtained by interpolation is 0.26 mg./g. and at the higher level it is 0.24 mg./g. The microbiological niacin assay value on this sample was 0.30 mg./g. Considering normal experimental variation, this can be regarded as excellent agreement.

TABLE 1
Growth data on niacin bioassay

Supplement per 100 g.ration	Average weekly gain in grams
0	−4.3
0.1 mg. niacotinamide	−2.8
0.2	3.5
0.4	7.4
0.8	19.8
0.75 g. coffee powder	0.7
1.75 g. coffee powder	9.2

After the niacin activity of instant coffee powder was confirmed by bioassay, the more convenient microbiological assay procedure was used to measure niacin in a number of retail brands. The niacin contents of 10 brands of regular instant coffee powder were as follows (mg. per g.): (a) 0.22, (b) 0.25, (c) 0.25, (d) 0.25, (e) 0.30, (f) 0.33, (g) 0.37, (h) 0.38, (i)

* This work was sponsored by the Coffee Brewing Institute, 551 5th Avenue, New York, New York.

0.42, (j) 0.53. This variation may be attributed to degree of roast of the coffee from which each powder was prepared or to greater or lesser extraction. Two samples of decaffeinated instant coffee powder contained 0.37 and 0.41 mg. niacin per g.

Taking the average niacin value of 0.33 mg. per g. of regular instant coffee powder, a cup of coffee made with one teaspoon of powder (approximately 3.5 g.) would contain 1.16 mg. niacin. The National Research Council's daily dietary allowance for the normal adult male is 15 mg. and the minimum daily requirement given by the Food and Drug Administration is 10 mg. On this basis a cup of coffee prepared with one teaspoon of instant powder would contain enough niacin to supply about 8% of the dietary allowance and about 12% of the minimum daily requirement. In the United States the niacin requirement can be obtained easily from an average balanced diet and niacin deficiency, though once a serious problem, is rarely observed in this country today. There are some areas of the world in which pellagra (not necessarily simple niacin deficiency) is not uncommon. In view of the fact that coffee is widely consumed as an enjoyment beverage, it behooves nutritionists to take into account the niacin that enters the diet from this source.

Table 2 gives values for eight B-vitamins other than niacin. No thiamine could be measured. The other vitamins were present in measurable amounts but at low levels in comparison to daily dietary requirements.

Table 3 shows low levels of sodium, calcium, total iron and fluorine in instant coffee powder.

TABLE 2

B-vitamins in instant coffee powder

	Micrograms per gram
Niacin	240
Thiamine	0
Riboflavin	16
Pantothenic acid	4.0
Choline	1,450
Folic acid	0.62
Citrovorum factor	0.20
Vitamin B_6	0.32
Vitamin B_{12}	0.0025

TABLE 3

Minerals in instant coffee powder

Sodium	0.03 mg./g.
Calcium	0.10 mg./g.
Iron	0.06 mg./g.
Fluorine	1.7 p.p.m.

SUMMARY

The presence of an average of 0.33 mg. niacin per gram of instant coffee powder was confirmed by bioassay. Regular instant coffee powder contained from 0.22 to 0.53 mg. niacin per gram. Two samples of decaffeinated instant coffee powder contained 0.37 and 0.41 mg. niacin per g. Measurable, but low, levels of eight other B vitamins and of sodium, calcium, iron and fluorine were found in instant coffee powder.

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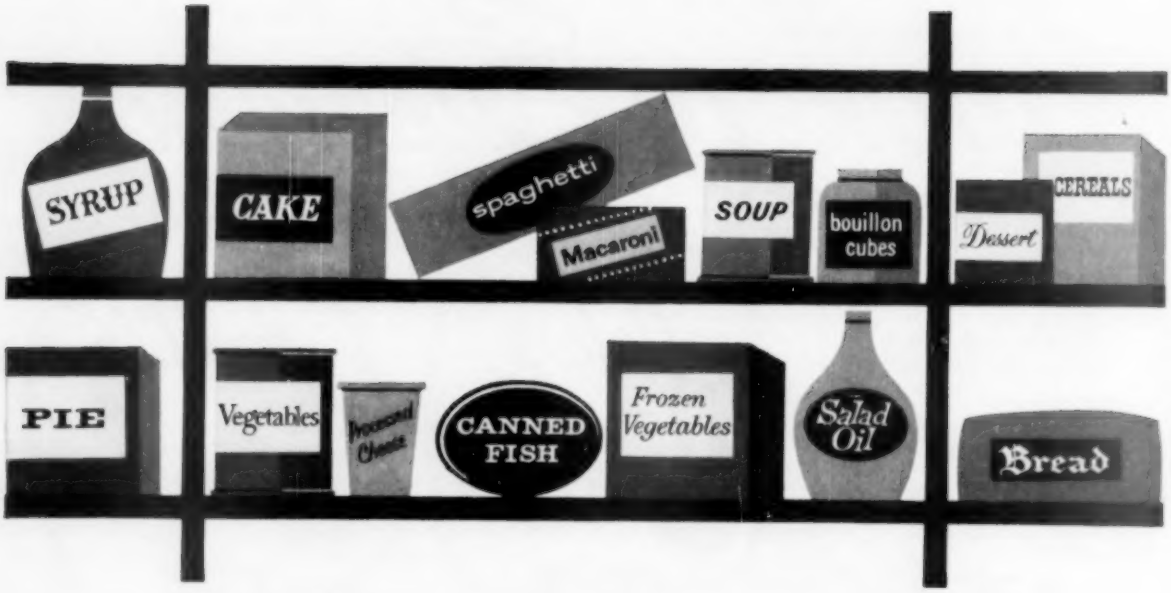

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Aluminum from the Can Maker's Point of View

L. P. Gotsch, R. W. Pilcher[a] and R. H. Lueck[b]
American Can Company

CURRENT INTEREST manifested in aluminum cans arises in large part from the steady expansion of aluminum-producing facilities in the United States and Canada over the past eighteen years. Initiated early in World War II to meet military demands, this expansion has carried over into the post-war era in the form of enlargement of existing facilities and construction of new facilities by major producers. Exploration has established a favorable picture for the long range availability of raw materials for aluminum production and sustained development activities have disclosed new and unique applications for the metal. These combined considerations account in part for the entry of new companies into the aluminum-producing field with further increases in production capacity.

Saturation of military and strategic uses for aluminum has developed during recent years the necessity for new, large tonnage uses for the metal to sustain current and estimated future production. The can manufacturing industry with an annual consumption of some 5 million net tons of tin mill products presents an attractive target. Technologically, or from the standpoint of product applications for which aluminum cans should be satisfactory, a substantial fraction of this tonnage could be converted employing established can making techniques with only minor modifications. This market, if developed, would be a major outlet for aluminum as compared to many of its uses today.

THE CAN MAKER'S VIEWPOINT

The can maker's viewpoint with respect to the use of metals other than tin plate parallels closely that of the packaging man. Tin cans are made and merchandised for specific end applications. More than 50 years of research and commercial development have established tin cans as low-cost containers with a wide spectrum of product applications. They are produced by high-speed automated methods at conversion costs lower than the cost of their component materials. Tin cans may be engineered both to withstand high-speed volume handling and to give service life adequate for commercial requirements.

In his forecast on the use of aluminum for these established products, the can maker therefore has two principal concerns: (1) how well the aluminum cans match performance-wise the standards set by tin, and (2) whether aluminum can be competitive cost-wise.

RESEARCH BACKGROUND

Can makers have had a long-time interest in aluminum for their own esoteric reasons. Economically, it would be desirable to have a working alternate or competitor for tin plate. Technologically, aluminum would eliminate periodic problems with tin plate cans in certain product applications, where rusting or discoloration due to sulfur-bearing commodities historically have been encountered. Commercially, the desirability of having a domestically-available material to avoid the impact of official restrictions placed on the use of imported tin during national emergencies, is obvious *(1)*.

Our own experimental activities originated in the post World War I period. By the early 1930's, application of drawn aluminum cans to Pacific Coast fish products was tested. In 1944 and 1946, extensive packs of major canned foods were made in two-piece aluminum cans to establish performance parameters of products of varying corrosivity. This work was facilitated by the early release of aluminum from official restriction and allocation. Of passing interest is the fact that aluminum was released from restriction prior to tin plate. The most sustained experimental effort on aluminum was in connection with a research and development program initiated in 1950 to develop tin plate alternates. This effort is continued today.

In the past, economic considerations have always precluded commercial exploitation of aluminum. This is unlike the postwar situation in Europe where continuing restrictions of steel for tin plate use in some countries and the domestic unavailability of steel in others have made the use of aluminum cans for foods economically feasible in certain instances *(3)*. With the possibility, however, that the economics of the sometime future in the U. S. will also favor aluminum, our experimental activities have been continued to establish the technological applications and engineering requirements involved in the use of this metal as an alternate to tin plate.

MANUFACTURING METHODS FOR ALUMINUM CONTAINERS

Soldered cans—three-piece containers. High-speed, low-cost manufacturing procedures for the 3-piece food containers made from tin plate are for the most part based upon its easy soldering characteristics. With non-corrosive fluxes and relatively low heat, solder will wet and flow into side seams in fractions of seconds and produce a strong, stable joint. Unfortunately, this situation does not exist with aluminum.

It is true that aluminum is being soldered today for a number of industrial operations; however the procedures required

[a] Research Division, Barrington, Illinois.
[b] Vice President of Research, New York.

are far from being adaptable to an economical can making machine. By tin plate standards, the fluxes required are extremely corrosive, the soldering temperature high and the solder flow impossibly slow. The best solders from the mechanical standpoint give joints susceptible to electrochemical corrosion of the bimetallic type. The only chemically stable solders known to date are brittle and weak to begin with or become so due to metallurgical instability. Both the aluminum producers and can makers have put a considerable effort into solving this problem, but possibilities of ever producing a good quality soldered aluminum can are very dim at this time.

Side seam cemented cans—three-piece containers. Side seam cemented aluminum containers, on the other hand, can be made at the speed and efficiencies of cemented tin plate cans by use of modified conventional bodymakers and side seamers. This technique was developed for both sanitary can side seam and key-open, collar can side seam constructions in the early 1950's.

In 1956, in collaboration with an aluminum producer and an oil company, some 50,000 cemented side seam aluminum quart motor oil cans were made on commercial can making equipment, packed, and test-marketed in one locality *(2)*. Success of this initial test led to commercial production in 1958. Currently several million containers are being made for motor oil by American Can and other can manufacturers. The economics of this venture are said to be based on the value of the scrap recovery program in which the filling station operators sell the empty cans back to the aluminum producers as high quality scrap.

Modifications in the conventional can making lines to accommodate aluminum plate are ecomparatively minor. Some tools or parts must be made of other materials, certain actuating and transfer mechanisms modified to avoid distortion of the soft metal, and all magnetic controls and devices replaced with mechanical counterparts.

Altbough there are no frictional problems when both sides of the aluminum are organically coated, special lubricating materials and techniques are required to make container parts with one or both sides unenameled in the interest of economy. These are necessary not only to overcome the high friction of aluminum to other metal machinery parts but also to circumvent the development of an unsightly black discoloration which appears after a time. This is believed to be an accumulation of aluminum dust and/or oxide on the machine parts which transfers in smears to the can surface.

Present cemented side seam cans, whether made of tin plate, steel or aluminum, are limited with respect to product applications. They are applied only to products to which the cements are chemically resistant. They are not applied where the cans are subjected to severe packaging or market handling or where internal can vacuums or pressures are required in the end applications. These latter limitations apply to pressure processed food products, beverages containing carbonation, and the so-called pressurized products. In such applications, the side seam cemented cans of today are inadequate.

Drawing—two-piece containers. Production of 2-piece aluminum cans with a conventional end applied to a drawn body has been utilized for experimental or pilot line purposes in the United States. This method of manufacture which requires trimming after drawing is employed commercially in Europe *(3)*.

Although useful for our current test purposes, drawing has several major limitations as far as American can making practices are concerned. The first limitation is that of the can sizes which can be produced by this method. In general, only containers with a smaller height than diameter can be made. This is in contrast with 3-piece tin plate cans whose comparable ratios are usually greater than unity. The implication of this container size limitation to the packager whose plant facilities are engineered to transport and otherwise handle tin cans, is obvious.

A second limitation of the drawing method is that the conversion cost is substantially higher than in the 3-piece container manufacturing procedure. Underlying factors in this connection are the relatively slow production speed and the larger area of sheet metal required per container.

Procedures unique to aluminum. The first of these is the Keller Process used commercially in Europe *(3)*. This method produces deep-drawn aluminum bodies with height-diameter ratios greater than unity. The process starts with a circular blank of greater diameter than the final can and forms the body by cupping and a series of ironing operations, followed by trimming. The process permits application of any desired bottom end profile or body beading to enhance container strength. By American standards, the top production speed of single units is slow, and multiple units are required to give conventional can production capacities.

Impact extrusion is also used commercially in Europe to give aluminum can height-diameter ratios greater than unity. Cans produced by this principle have excellent strength and are supplied commercially for pressurized products *(4)*. Two techniques may be applied in impact extrusion: reverse extrusion whereby a single container body with or without an integral bottom end is formed, and forward extrusion in which a long cylinder equivalent in length to several can heights is produced from which a number of individual container bodies will be cut. Neither of these methods can take advantage of the high speed, low cost flat sheet metal coating and decorating procedures and equipment available today. Each ironed or extruded container must be thoroughly freed of lubricant by washing and then individually coated or lithographed and baked.

Other unique procedures for aluminum cans have thus far received only experimental attention and are mentioned primarily in the interests of completeness. These are high frequency electrical side seam welding and cold or pressure side seam welding. The latter phenomenon is characteristic of soft non-ferrous metals, such as aluminum, and probably will need to be ultrasonically assisted to be practical.

CHARACTERISTICS OF ALUMINUM CONTAINERS

It was stated earlier that the extent to which aluminum cans will replace tin plate containers will be determined largely by their ability to match performance-wise the standards set by tin plate cans. A few of these requirements important to the food packer can be reviewed here.

Strength. It is unnecessary to describe in detail the importance of strength of container materials and containers in modern can making and packaging operations. It should suffice merely to list those operations involving physical or mechanical stresses which can materials and finished cans are expected to withstand.

In can making the metal should withstand without damage in sheet, cylinder or final container form forces due to (a) high speed mechanical transfer or movement, (b) cable, elevator, or runway transport impacts; and (c) car or carrier loading. Packaging plants impose similar stresses in unloading and conveying empty containers to storage, to the packaging line, or from storage to the line. Packaging stresses on cans will depend on the particular product applications. However, a representative list would include various combinations of stresses due to filling and closing; still retort crate loading and dumping; continuous cooker operations; pressure processing; cooling; can unscrambling; labeling and casing; warehousing and shipping.

The fact that aluminum, on a gauge for gauge basis, is not as strong as steel is well accepted. The problem

then becomes one of what can be done to engineer the required strength into aluminum food cans. Since end buckling, body side wall paneling and denting due to mechanical abuse are the measures of strength as the packer sees them, some data can be shown which pretty well define the problem.

In Figure 1 are shown the internal pressures required to buckle 307 diameter ends made from aluminum. Illustrated here is the ability to markedly

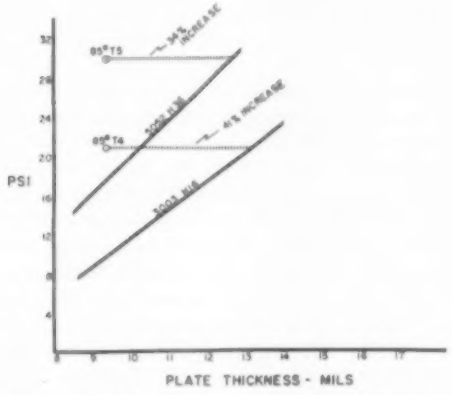

Figure 1. Buckling pressure of No. 2 sanitary can ends. Aluminum vs. tinplate.

increase the strength by alloying with magnesium as we compare 3003, a low magnesium content alloy with 5052, one of the higher alloys. On this same chart we have spotted two points which represent the expected buckling pressure of these same ends made from both low phosphorous and high phosphorous steels. In order to match T5 (high strength) steel, the high strength 5052 aluminum alloy would have to be used at 34% increase in gauge. It is almost as strong as the T4 (low strength) tin plate but, as will be shown later, probably will not serve as an alternate because of its low resistance to the same type of corrosion hazard that makes us specify the low phosphorous steel. From a corrosion resistance point of view the products which would require a T4 steel would most likely require a low magnesium content aluminum. In these instances the strength must be compared with 3003 alloy where approximately 40% gauge increase is required for equivalent strength.

In Figure 2 is seen the same comparison made for paneling resistance. Unfortunately no suitable soldered cans were available but the data on 401 x 411 cemented cans should suffice to illustrate the point. Here again a 35% gauge increase is indicated.

In the laboratory one can devise a variety of can abuse tests to check resistance to mechanical handling damage, but translation of these into practical terms is sometimes difficult. Recent experiments with commercial sized rail shipments of filled aluminum antifreeze containers illustrate in a practical way what we believe to be true from laboratory tests. Figure 3 compares the dents observed after shipment and

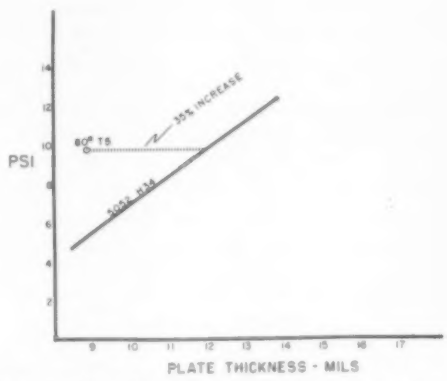

Figure 2. Paneling pressure of 1 qt. 401 x 411 cemented cans. Aluminum vs. tinplate.

shows the markedly lower resistance of the aluminum cans to denting even though a high magnesium alloy at a thickness 20% over the usual tin plate gauge was used.

The exact increases in gauge required for aluminum must be worked out for each specific can size and product application. The corresponding increase in the amount of metal used of course will result in higher can prices. In this regard it may be noted that the preceding charts are based on H36 and H16 tempers which are 3/4 Hard on the basis of old and perhaps more familiar nomenclature. Although this temper is still ductile enough for can making purposes, the next step up in strain hardening to achieve greater strength results in physical properties undesirable in can manufacture.

Other devices to reduce the aluminum gauge requirements could be envisioned, such as modification of the end profile geometry or the introduction of beads into the can body. These have been looked into experimentally, but everything tried works with equal effect on the strength of tin plate cans and the relative gauge requirements remain essentially unchanged. The same can be said for any modifications in can packing or handling practices, such as pressure cooling after retorting, elimination of mechanical un-

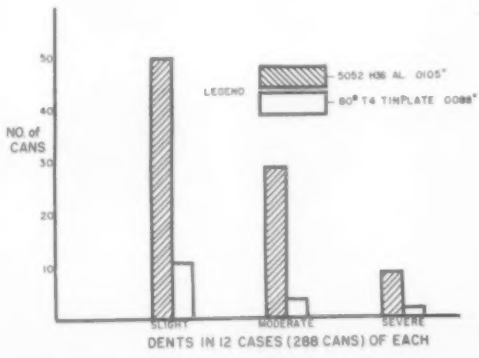

Figure 3. Shipping test—1 qt. anti-freeze, Rail car with 45 case pallets.

Figure 4. Corrosion performance of aluminum cans. (Inside enameled drawn 307 x 112 cans)

Alloy	Mg. content	Tomato juice 7 months at		Orange drink 4 months at		Corned beef hash 4 months at	
		70° F.	98° F.	70° F.	98° F.	70° F.	98° F.
1100	Trace	0.5[1]	0.9[1]	0.4[1]	0.5[1]	0.6[1,2]	1.0[1,2]
3003	Trace	0.6	0.7	0.1	0.0	0.6	1.2
3004	1.0%	2.4	5.3	1.7	CF-5 Mo.	0.2	0.3
5050	1.4	2.7	CF-7 Mo.	2.8	CF-3 Mo.	....	....
5052	2.5	3.8	CF-6 Mo.	....	....	0.4	0.3
5154	3.5	5.8	CF-7 Mo.	4.2	CF-3 Mo.	....	....
5086	4.0	CF[3]-6 Mo.	CF-4-Mo.	11.1	CF-2 Mo.	....	....

[1] Vacuum loss expressed as milliliters can volume increase.
[2] Estimated from flip vacuum loss data.
[3] Corrosion failure.

scramblers, or use of more rugged and protective shipping cases.

Shelf life. It was stated earlier that the ability to take advantage of the higher strength magnesium alloys would be limited by the corrosivity of the product to be packed. Data typical of those on which this statement is based are shown in part by Figure 4. The alloys are listed in the increasing order of magnesium content and strength. In parallel columns are shown vacuum loss measurements through the development of hydrogen within the sealed cans during storage. These measurements were made by the conventional, non-destructive can volume increase and flip vacuum methods commonly employed to follow changes in internal vacuums induced by corrosion of the can by its contents.

From the data both at room temperature (70° F.) storage and elevated (98° F.) temperature, it is evident that for tomato juice, a moderately corrosive product, and a non-carbonated orange beverage, a highly corrosive product, utilization of the high magnesium alloys in cans would be at a considerable sacrifice of corrosion resistance. For mildly corrosive products, such as corned beef hash and tuna, the presence of magnesium apparently is unimportant and these alloys might be used to advantage.

These data are from test packs involving drawn 307 x 113 inside enameled containers. A considerable number of such packs with a variety of food products have been made to assess the effect of alloys, the need for anodizing or enameling, and storage conditions for their effect on corrosion of the containers and organoleptic qualities of the product. These tests will require further storage for completion and the information obtained will be the subject of another report.

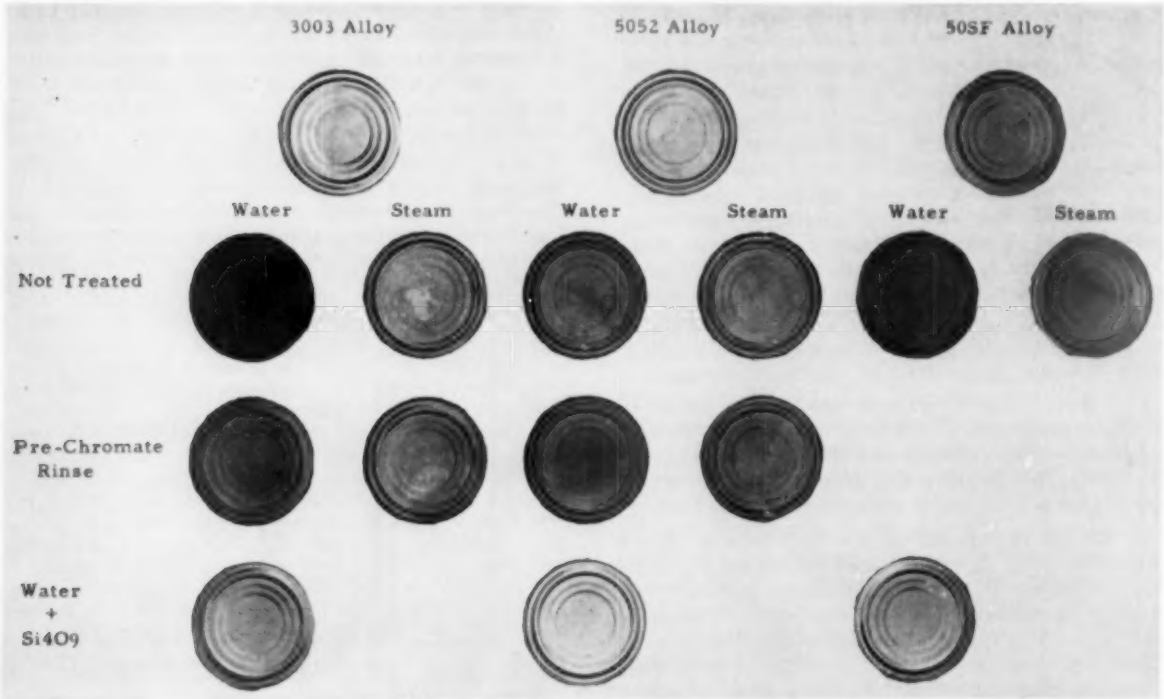

Figure 5. Retort discoloration of aluminum containers.

The anticipation that the higher strength alloys would be found commercially satisfactory for certain product applications from the corrosion and organoleptic point of view, is well evidenced by a comprehensive test pack of salmon and tuna started in 1955 in Canada in collaboration with an aluminum producer. Eight container variables based upon two alloys, two enamels and plain and anodized plate were tested in the form of 307 x 113 cans.

Data thus far suggest that all containers tested will show satisfactory performance, product-wise, with tuna. Data on the salmon packs, which included 4 species of the fish, indicate that all can variables tested will show satisfactory performance with the exception of the inside plain untreated and treated aluminum alloys. No significant differences in corrosion of the inside enameled cans are discernible, due to the different species of fish.

Appearance. The characteristic appearance of new-bright aluminum cans certainly is pleasing and a worthy competitor to tin plate cans in this regard. Experience with can making and test use has shown, unfortunately, that this pleasant appearance is more subject to deterioration with aluminum than with tin plate, and measures must be taken to guard against this during processing. While aluminum does not show red rust which can be an occasional problem with tin plate, under processing conditions it does rapidly oxidize and takes on an unattractive dull, gray finish. Figure 5 shows this effect produced during underwater processing and its control by the use of a silicate-treated water. No practical method of preventing this discoloration of plain aluminum during conventional retort processing in steam has yet been found. Retention during processing of a bright, shiny appearance in aluminum cans requires their outside protection by anodizing the plate or coating with a transparent lacquer prior to can manufacture.

ECONOMICS OF ALUMINUM CONTAINERS

The immediate post World War II years saw a steady decrease in the economic disadvantage of aluminum containers due to the cost of the metal. Expanding aluminum facilities helped dampen the price increases during an inflating economy. The post 1950 trend, however, has been in an opposite direction and, until the very recent aluminum price cut, aluminum prices had been increasing faster than those of tin plate. The aluminum industry clearly recognizes that it has a "job shop" operation by comparison with continuous tin plate rolling mill practices and, given the proper volume, could reduce prices of aluminum sheets for a mass market. It is equally true, however, that the most optimistic projections do not bring the price of aluminum in line, even on a gauge-for-gauge substitution for tin plate.

On the basis of the can strength data shown, substitution of aluminum at equivalent, or near-equivalent, gauge is most certainly going to require some costly revisions in can packing and handling procedures. A 20% gauge increase over tin plate would moderate these somewhat and 35% or more would be required to essentially eliminate them. The economic disadvantage of aluminum is further increased by the necessity to outside anodize or outside enamel to prevent discoloration where plain tin plate is now used satisfactorily.

Another facet to the economic picture is the problem of developing commercial procedures for converting aluminum into cans which will compete with the low conversion costs for tin plate. For the limited product areas where side seam cemented containers can be employed, the problem is not great. On the other hand one of the major economic difficulties associated with the extrusion or deep drawing procedures for making seamless bodies is the necessity for inside and outside coating or lithographing each body individually. Sacrificed in this instance is the great economy involved in flat sheet roller coating or offset lithographing at high speeds, each sheet carrying a multiplicity of body blank layouts.

One aspect of the cost picture where aluminum may have an advantage is in the freight savings resulting from lighter can weights. It is difficult to develop a dollars and cents estimate of what these savings might be because of the extreme complexity of shipping rates and practices. One thing that can be said is that savings will only be effected on that portion of the shipment which exceeds the minimum weight requirements. The freight cost picture will have to be analyzed for each circumstance and, at that, probably will not result in a firm figure without some actual shipment experience.

CONCLUSION

Aluminum containers are available today only at a considerable price disadvantage with respect to their tin plate counterparts. The probability that future price reductions will break this pricing structure depends squarely on the extent of reduction in aluminum prices.

There is little question but that a satisfactory aluminum container can ultimately be engineered for many of the food products now packaged in tin plate cans. This engineering, through the necessity of increased gauges and extra enameling costs, will add to the initial economic disadvantage already imposed by the cost of the metal. The extent to which this situation can be relieved will also depend upon the willingness of the packer to modify specific packing and handling operations so as to be suitable for the more easily damaged aluminum cans.

Except for certain product areas where inside sulfide discoloration and rusting during shipment or storage are problems with tin plate, there appears to be no real performance advantage for aluminum which would justify a higher cost container. The value of a problematical consumer eye-appeal or other psychological advantages cannot be assessed on a technical basis.

In view of the long range importance of the potential of aluminum containers, can makers will continue efforts toward developing the can making and can using know-how required to make aluminum containers commercially desired and economic realities. They cannot do this alone, however, and the future will depend in the final analysis on the cost of aluminum versus tin plate.

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Notes and Letters

Determination of Gas Space in Pulverant Solids

The gas space in packages of such diverse products as instant coffee and marbles may be readily determined by means of a simple device (Figure 1) easily assembled from standard items of laboratory equipment.

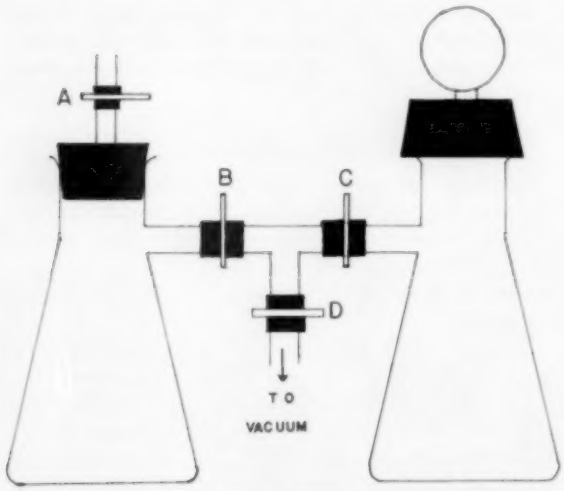

Figure 1. Device for determining gas space in pulverant solids.

Step 1. Fill left flask with material under test. Insert stopper with clamp "A" open. Close "A" clamp.
Step 2. With clamp "B" closed and clamp "C" and "D" open, evacuate right flask. Close "D" clamp, read P_I.
Step 3. Open "B" clamp, read P_F.
Note: In the above, P is atmospheric pressure. Where a sealed can is substituted for the left hand flask, P is the pressure in the can.

In simplest form the sidearms of two suction flasks are connected with pressure tubing with a "T" between them. Flask "A" is filled with the product to be tested and stopped. Flask "B" is fitted with a stopper with a vacuum gage. The open line from the T is connected to a vacuum pump or aspirator. In use, a clamp is placed close to the T on the "A" side. Flask "B" is the evacuated and the initial pressure (P_I) read. The vacuum line is then clamped off and the first clamp released. The pressure (P_F) is again read.

The volume of gas in Flask "A," Vg, expressed as a fraction of the volume of Flask B, V_B, is given by the formula:

$$Vg = \left(\frac{P_F - P_I}{P - P_F}\right) V_B \quad \text{where P is the initial pressure in Flask "A"} \qquad (1)$$

The values for P, P_F and P_I in equation (1) are in absolute pressure so that readings of a vacuum gage must be converted to pressure readings. Of course units must be consistent.

Equation (1) may be modified to permit the direct substitution of vacuum gage readings as follows:

$$Vg = \left(\frac{P_I' - P_F'}{P_F' - P'}\right) V_B, \quad \text{where the prime indicate vacuum gage readings.} \qquad (2)$$

Where $V_A = V_B$, V_B may be taken as 100 so that Vg may be expressed as per cent of total space occupied by solids. Vg may be determined whether V_A is or is not known, provided V_B is known. In measuring V_A and V_B the volume represented by tubing, etc. should be included with the volumes of the respective flasks. Samples and apparatus should be at ambient temperature.

This device may be used on samples in sealed cans by attaching a can-puncturing device with attached compound gage and valve.

Don Scott and Frank E. Hammer
Fermco Laboratories, Inc.
4941 S. Racine Ave.
Chicago 9, Ill.

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Any member of the Institute of Food Technologists may make nominations for the award. Each nomination must be in letter form and include the following:

a. Name of Company or Institution.

b. Name of Product and/or Process.

c. Description of Product or Process.

d. Statement of reason for considering this a meritorious achievement.

e. Statement listing individuals chiefly responsible for the achievement and their individual contributions.

f. Statement indicating the time and extent of commercial utilization.

Nominations must not exceed three, single-spaced, typewritten pages. Nominations should be sent to:

Institute of Food Technologists
176 West Adams Street
Chicago 3, Illinois

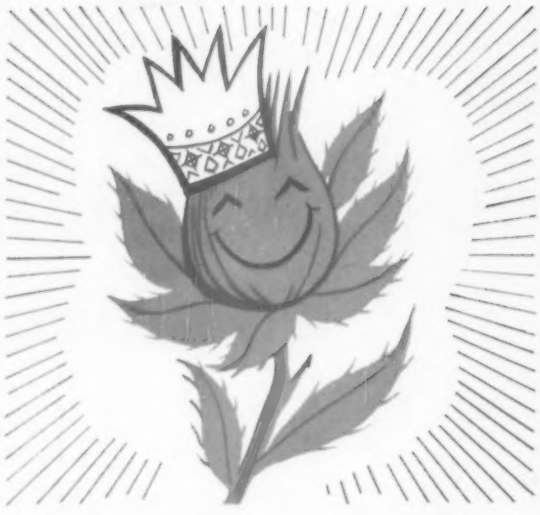
To be considered nominations must be postmarked not later than December 10, 1958.

REGIONAL NEWS

Phi Tau Sigma Elects National Officers

At the Fourth National Meeting of Phi Tau Sigma, the food science honor society, at the Palmer House in Chicago, the following national officers of the Society assumed office: President—Samuel A. Goldblith, Massachusetts Institute of Technology; Vice-President— Fred C. Baselt, American Can Company; Secretary-Treasurer—Robert E. Buck, H. J. Heinz Company; Executive Secretary—Gideon E. Livingston, University of Massachusetts; Assistant Executive Secretary—F. Miles Sawyer, University of Massachusetts.

With the granting of a charter to the University of Wisconsin, the Society now has seven chapters. (The others are at the University of Massachusetts, Rutgers University, the Massachusetts Institute of Technology, the University of Georgia, Cornell University and Michigan State University.) The Society publishes *The Food Scientist*, under the direction of R. E. Morse of Rutgers University, editor and W. D. Powrie, Michigan State University, associate editor.



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S. CALIFORNIA

Dr. Borsook Named Food Man of the Year

SCIFTS has singled out Dr. Henry Borsook, Professor of Biochemistry at the California Institute of Technology, as their choice for the *1958 Food Man of the Year*. The Certificate of Recognition, traditionally awarded at the regular September meeting of the Section, will be presented by C. Gordon Beisel, Chairman of Southern California Section.

The citation as *Food Man of the Year* is a method of giving recognition to a person who has made an outstanding contribution in the realm of food technology. Dr. Borsook's untiring efforts in the development of a Multi-Purpose Food as Research Director of Meals for Millions Foundation, Inc. has won him this distinction.

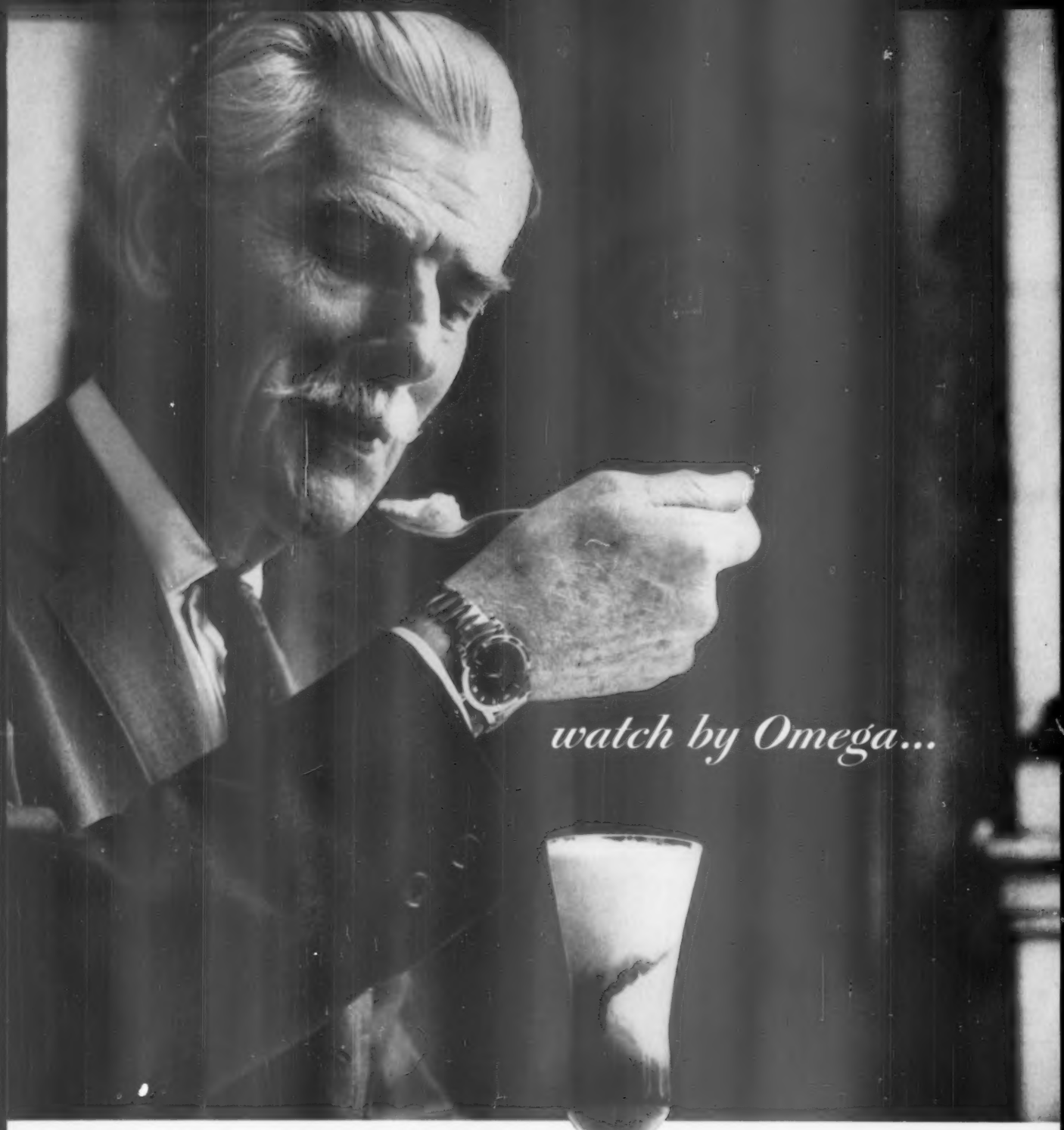
Dr. Borsook was born in England, but when he was ten years old the family emigrated to Toronto, Canada where he remained until he became associated with Caltech in 1929. His formal training has been in the field of medicine and biochemistry and he holds the B.A., M.A., Ph.D., M.B., and M.D. degrees from the University of Toronto, where he also received numerous prizes and honors.

His connection with Meals for Millions began in 1944 when he was approached by Clifford E. Clinton, founder of the Clifton Cafeterias, and asked to develop a food with the following specifications:

Three servings were to supply the Recommended Daily Allowances of protein, minerals, Vitamins A, thiamine, riboflavin, and niacin. The food was to be palatable, to blend readily with other foods when other foods were available, to be eaten by itself when they were not. The meal had to be quickly cooked, in not more than 10 minutes, and require only the most rudimentary cooking equipment. It had to keep from six months to a year, packaged in a dry state. It was to cost not more than five cents a meal. (The result actually cost only 3 cents). It could not offend the religious principles of any people. It had to be transported easily. It could not draw on those foods which Americans eat to a large extent.

The major ingredient chosen finally was soy grits, with a low fat content. The soy protein was chosen because it was the best cheap protein from a nutritional point of view. Soy grits have a good texture. One need add only water to make a good soup. If only a little water is added, it is a stew. It can also be used as a meat extender. To the grits were added the vitamins so that two ounces would supply one-third of the Recommended Daily Allowances of protein and these vitamins.

Clinton established "Meals for Millions" as a non-profit Foundation to handle the world-wide aspects of this high-protein food in combatting starvation. He appointed Dr. Borsook to the Board as Research Director. The Foundation has always stressed Dr. Borsook's original statement that Multi-Purpose Food was an example and only an example of what can



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be done by the application of the science of nutrition and modern food technology. In addition to the work with Meals for Millions Foundation, Dr. Borsook gives generously of his time for other public services. He has served on the Food and Nutrition Board of the National Research Council, the Committee on Nutrition of Industrial Workers of the National Research Council, the California Nutrition Committee, and others. He serves as consultant for several hospitals in the Los Angeles area and is active in a number of administrative committees at Caltech.

Mohawk Valley Regional Section

Guest speaker B. Gerald Klein, Technical Representative of The Hubinger Company, Keokuk, Iowa presented the subject "Automation of Bulk Syrup Handling" to members and guests of the Mohawk Valley Regional Section, Institute of Food Technologists, at the May meeting. The Section met in St. Johnsville for a tour of Hubinger's Bulk Syrup Station to observe examples of modern engineering methods applied to receiving, storing, and handling deliveries of bulk corn syrup. Following the inspection tour a buffet supper was enjoyed in the banquet hall of The Manor.

Mr. Klein's talk was based on his experiences throughout the United States in the specialized field of planning and engineering construction of bulk handling systems for such products as corn syrups, cane sugar syrup, refined corn starches, and brewer's grits.

William F. Nye, Jr.

LITERATURE ON FOOD RESEARCH AND TECHNOLOGY [1]

Commodities

The AMIF sausage starter culture: background, questions, answers. C. F. Niven, jr., Robert H. Deibel, and George D. Wilson. Chicago, 1958. (American Meat Institute Foundation. Circular no. 41.)

Commercial fruit and vegetable products; a textbook. 4th ed. W. V. Cruess. New York, McGraw-Hill, 1958. 891 p. $15.00. With new information on improvements made in food processing and preservation.

Das Getreide, Tom 2. Das Getreide und seine Untersuchung.

[1] Material for this list should be sent to Dr. James G. Hodgson, Chief, Library Branch, Quartermaster Food and Container Institute for the Armed Forces, 1819 W. Pershing Road, Chicago 9, Illinois.

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Matéi Rohrlich and Gerhard Brückner. Berlin, Hayn, 1957. 182 p. (Grundlagen und Fortschritte d. Lebensmitteluntersuchung, Bd. 4.) Marks 27.00.

International sugar economic year book and directory, 1958–59. London, Publishing and Distribut. Co., 1958. 470 p. 70 s.

Meet your meats. Bertha Clow, Bozeman, Mont., 1958. (Montana Agricultural Experiment Station. Bulletin, 541.) pap. apply. How Montanans like their meats.

Preparation of candied fruits and related products. Part III. Laboratory control. F. E. Atkinson and C. C. Strachan. Ottawa, Canada, Canada Department of Agriculture, 1957. 31 p. (SP 11) pap. apply.

Die Reismüllerei. Ein Lehr- und Handbuch für alle Probleme d. Reisbearbeitung. Detwold, Germany, Shäfer, 1957. 127 p. Marks 10.80.

Studies on beef quality. Part VI. P. E. Bouton, A. Howard, and R. A. Lawrie. London, H. M. Stn. Off., 1957. (Gt. Br. Dept. of Scientific and Industrial Research. Food investigations. Special report no. 66.)

Food Engineering

Formulaire du froid; 3d ed. René Martel. Paris, Technique et Vulgarisation, 1958. 388 p. 975 Franks.

Quick frozen foods: the commerce and technology of processing, packaging and distribution. John L. Rogers. London, Food Trade Press, 1958. 340 p. 50 s.

Chemical Aspects

Amino acid supplementation. E. E. Howe. Borden's Review of Nutritional Research, v. 19, no. 2, Mar. Ap. 1958. p. 10–34.

Chemie der Eiweiskörpen, umgearb. Aufl. Ernst Waldschmidt-Leitz. Stuttgart, Enke, 1957. 222 p. (Sammlung chemischer und chemisch-technischer Beiträge, N.P. nr. 49.) Marks 32.00. First issued in 1951. New edition covers literature to 1955.

Congress of Modern Analytical Chemistry in Industry, St. Andrews, June 1957. Proceedings. Cambridge, England, Heffer, 1958. 244 p. 42 s.

An introduction to electronic absorption spectroscopy in organic chemistry. [2nd ed.] Albert E. Gillam and E. S. Stern. New York, St. Martin's Press, 1958. $10.00. An import. *Processed plant protein foodstuffs.* A. M. Altschul, ed., New York, Academic Press, Inc., 1958. 955 p. $26.00.

Progress in sterochemistry, v. 2. W. Klyne and P.B.D. de la Mare, eds. New York, Academic Press, 1958. 323 p. Literature in general up to late 1956.

Progress in the chemistry of fats and other lipids, v. 5. Advances in technology. R. T. Holman, W. O. Lundberg, and T. Malkin, eds. New York, Pergamon Press, 1958. 338 p. $14.00. Originated in England but with a number of American contributors.

Scienza e alimentazione. A. L. Bacharach. Milan, Italy, Bompiana, 1957. 217 p. 700 Lire.

Solvent extraction in analytical chemistry. George H. Morrison and Henry Freiser. New York, John Wiley, 1957. 269 p. $6.75.

Unit processes in organic synthesis; 5th ed. Philip H. Groggins. New York, McGraw-Hill, 1958. 1080 p. $17.50. First issued in 1935.

Physical Aspects

Modern electroanalytical method. G. Charlot, ed. Princeton, N. J., D. Van Nostrand, 1958, 186 p. $4.95. Proceedings of the International Symposium on Modern Electrochemical Methods of Analysis, Paris, 1957. Fourteen of the contributions are in English.

Biological Aspects

Protides of the biological fluids. H. Peeters Ed. Princeton, N. J., D. Van Nostrand, 1958. 264 p. $8.50. Proceedings of the Fifth Colloquium on Protides of the Biological Fluids, Bruges (Belgium), 1957. Summaries in English for articles not presented in English.

Bibliographies

Bibliography of food; a select international bibliography of nutrition, food technology and distribution, 1936–1956. E. Alan Baker and D. J. Foskett. New York, Academic Press, 1958. 331 p. $11.00. Authors are English librarians. Only published material is included.

A selected bibliography of research and development and its impact on the economy. Washington, U. S. Govt. Print. Off., 1958. 21 p. processed. (U. S. National Science Foundation. Office of Special Studies. NSF-58-18).

Serial publications of the Soviet Union, 1939–1957. Washington, U. S. Govt. Print. Off., 1958. 459 p. $2.75. Prepared by the Cyrillis Bibliographie Project, Library of Congress. A subject index brings out the periodicals devoted to food subjects.

Miscellaneous

Aviation medicine on the threshold of space; a symposium. Aviation Medicine, v. 29, no. 7, July 1958. p. 485–539. Two articles on feeding problems.

A directory of medical and biological research institutes in the U.S.S.R. David P. Gelfand. Washington, National Institutes of Health, 1958. 340 p. processed. (U. S. Public Health Service. Publication no. 587.) Subject index includes Nutrition and Metabolism, Biochemistry etc. showing the location of the research institutes.

Information and communication practice in industry. T. E. R. Singer, ed. New York, Reinhold Pub. Corp., 1958. 304 p. $8.75. The organization of special libraries in industry and means of communication with research staffs.

Successful process plant practices, operation, maintenance and safety. Robert L. Davidson. New York, McGraw-Hill, 1958. 324 p. $10.00.

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ANALYTICAL METHODS

New approach to continuous electrophoresis.

Dobry, R. and Finn, R. K. (Cornell Univ., Ithaca, N. Y.). *Science 127*, 697–8 (1958).

A new electrophoretic technique based on upward laminar motion is described. The potential field extends to a height of 40 in. When no potential is applied, the mixt. proceeds up the center of the column as a single ribbon and leaves through the middle duct at the top of the column. When a potential is applied, the single band splits up into several individual bands which under favorable conditions can be withdrawn through separate ducts at the top. Typical results obtained with a mixt. of fuchsin, bromthymol blue and bromphenol blue are described.

A simple spectrophotometric method for the determination of calcium.

Ferro, P. V. and Ham, A. B. (Dade Reagents, Inc., Miami, Fla.). *Am. J. Clin. Pathol. 28*, 208–17 (1957).

A simple, accurate spectrophotometric procedure is proposed for the detn. of calcium in serum and water. The method is based upon the pptn. of calcium by chloranilic acid and, with the use of tetrasodium ethylenediaminetetraacetic acid (EDTA-Na_4), the highly colored and sol. sodium salt is liberated to form a pink soln. The method provides remarkable reproducibility and accuracy of results.

Trace analyses by gas chromatography.

Bennett, C. E., Nogare, S. D., Safranski, L. W. and Lewis, C. D. (E. I. du Pont de Nemours and Co., Inc., Wilmington, Del.). *Anal. Chem. 30*, 898–902 (1958).

A gas chromatography app. suitable for analyses of impurities at the parts per million level utilizes an amplifier to increase the signal from a thermistor detector. Techniques necessary for obtaining low noise and drift levels are described. Several applications of the app. to trace analyses are discussed.

BIOLOGICAL SCIENCES

Biochemistry

A method for the separation of nucleotides by concave gradient elution.

Pontis, H. G. and Blumson, N. L. Dept. of Chem., Univ. of Durham, New Castle upon Tyne, Engl.). *Biochim. et Biophys. Acta 27*, 618–24 (1958).

A method is presented for the sepn. of nucleotides on ion-exchange resin, by concave gradient elution. An almost quant. procedure for the recovery of the nucleotides in the effluents is described and is applicable to org. acids, phosphoric esters, particularly sugar phosphates and in general to all anionic substances which can form calcium salts insol. in alc.-ether mixts.

Simplified colorimetric method for true glucose.

Athanail, G. and Cabaud, M. D. *J. Lab. Clin. Med. 51*, 321–3 (1958).

The condensation of glucose with 2-aminobiphenyl resulting in the formation of a characteristic color, the intensity of which is directly proportional to the quantity of glucose, has been adapted to a simple technical procedure using a single stable reagent. Values obtained by this procedure which may be used with either Folin-Wu or Somogyi-Nelson deprotenized filtrates reflect true blood glucose.

Studies on the enzyme dextransucrase. 1. The effect of pH on enzyme activity.

Neely, W. B. (Biochem. Lab., Dow Chem. Co.). *J. Am. Chem. Soc. 80*, 2010–13 (1958).

The Michaelis const. and maximum initial velocity for the enzymatic formation of dextran from sucrose were detd. at various hydrogen ion concns. A mechanism is postulated for the above results. The scheme that is presented indicates a bifunctional catalytic role for the enzyme. The pK values of the active sites correspond to a carboxyl and an imidazole group.

Transformation of ovalbumin into plakalbumin.

Ottesen, M. *Compt. rend. Lab. Carlsberg 30*, 211–70 (1958).

A review of the general mechanism of reaction between proteolytic enzymes and their substrates. The reaction between a proteolytic enzyme prepd. from *Bacillus subtilis* and ovalbumin is discussed in some detail. This work demonstrated that like the crude enzyme, subtilisin is able to transform ovalbumin into plakalbumin. The ratio between the proteinase activity and the plakalbumin forming activity of subtilisin was practically identical with that of the crude enzyme, in agreement with the hypothesis that only a single enzyme is responsible for plakalbumin formation. Some general features of proteolytic degradations are discussed with particular emphasis on the case of limited proteolysis.

Acetate utilization by liver and adipose tissue of rats fasted in the cold.

Perry, W. F. (Univ. of Manitoba, Winnipeg). *Can. J. Biochem. Physiol. 36*, 237–41 (1958).

The *in vitro* incorporation of 1-C^{14} and 2-C^{14} acetate into fatty acids and CO_2 by

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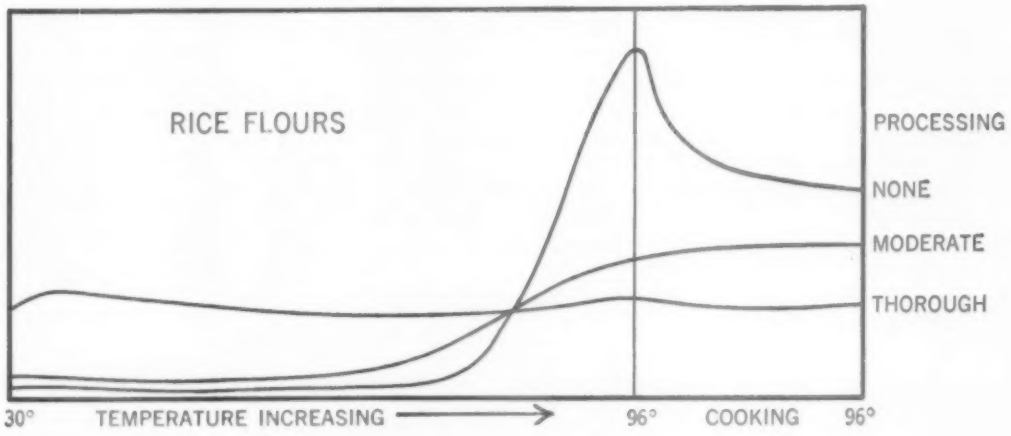

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Sústane 1-F	Flake	Inedible Tallow
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liver and adipose tissue was studied in rats fasted at 5° C. for 24 hrs. Compared with rats fed at room temp., there was a marked decrease in the incorporation of the acetate carbons into fatty acids and CO_2 by liver tissue. A pronounced decrease in acetate incorporation into fatty acid was also noted with adipose tissue from these same animals, but only a slight decrease in incorporation into CO_2. Addition of glucose to the incubation medium caused increases in fatty acid formation by liver and adipose tissue from both normal and fasted animals.

Chemical structure and biological activity.

BURGER, A. (Univ. of Virginia, Charlottesville). *J. Chem. Educ. 35*, 142–3 (1958).

Tables are presented which list the relationship of chem. structures and their respective biol. activities. This guide will enable both chemists and exptl. biologists to classify a compd. quickly and to find probable activities of the substance.

Microbiology

Studies on protein and nucleic acid turnover in growing cultures of yeast.

HALVORSON, H. N. (Dept. of Bacteriol., Univ. of Wisconsin, Madison). *Biochim. et Biophys. Acta 27*, 267–76 (1958).

The data indicate that protein breakdown in growing cells is only 4% of that in resting cells. The significance of the difference in protein and possibly nucleic acid stabilities of growing and resting cells is discussed.

Bacterial pyrogens.

BENNETT, I. L. AND CLUFF, L. E. (Johns Hopkins Hosp., Baltimore, Md.). *Pharmacol. Revs. 9*, 427–75 (1957).

The purpose of this review, is to describe concisely present concepts of the nature and structure of bacterial endotoxins, the pyrogenic or fever reactions they product, the mechanisms of these reactions, and to emphasize problems in this field that remain to be investigated.

Nutrition

Influence of diet on glucose tolerance.

URAM, J. A., FRIEDMAN, L. AND KLINE, O. L. (Div. of Nutrition, Food and Drug Admin., Washington, D. C.). *Am. J. Physiol. 192*, 521–4 (1958).

Observations are reported in which the curves obtained from the glucose tolerance test depend upon the nature of the diet on which the animals have been maintained. On a casein sucrose diet the glucose blood levels approach 200 mg. % as compared to 120 mg. % on a cereal ration.

Studies on the amino acids in the blood plasma of scorbutic guinea pigs.

RANGNEKER, P. V. AND DUGAL, L. P. (Dept. of Biol., Univ. of Ottawa, Can.). *Can. J. Biochem. Physiol. 36*, 25–7 (1958).

A comparative study is made on the plasma amino acids in scorbutic and normal guinea pigs. Arginine, threonine, hydroxyproline, and cystine are absent in the plasma of scorbutic guinea pigs while they are found to be present in the plasma of normal animals. A few amino acids have been estd. quantitatively. Plasma values of leucine, valine, alanine, glutamic acid, serine, and glycine are lower and the values of phenylalanine, lysine, and histidine are higher in scorbutic animals as compared with the resp. values in normal ones.

The effect of amino acids on the survival of the hyperthyroid rat.

BOLDT, R. E., HARPER, A. E. AND ELVEHJEM, C. A. (Dept. of Biochem., Univ. of Wisconsin, Madison). *Arch. Biochem. Biophys. 74*, 437–42 (1958).

Methionine, added to a casein diet which is complete for normal rats, markedly increases the survival time of hyperthyroid rats. That the improved survival is due to the labile methyl group of methionine is supported by the fact that betaine, another labile methyl-contg. compd., also increases the survival time of hyperthyroid rats.

Toxicology

Bioassay and chemical tests for food poisoning.

ANON. *J. Milk and Food Technol. 21*, 107–9 (1958).

This subcommittee consisting of Earl F. McFarren, reviewed the work that has been done in testing for staphylococcus food poisoning and paralytic shell fish poisoning. There have been some very recent advances in methodology of detg. the presence of potential food poisoning staphylococci in food, the probable source of staphylococci in incriminated food, and detg. the ability of individual strains of *Staphylococcus aureus* to produce enterotoxin.

Glass and metal fragments in foods and beverages.

ANON. *Assoc. Food and Drug Officials Quart. Bull. 22*, 24–6 (1958).

In an attempt to det. the potential hazards of glass and metal particles, feeding studies were carried out on dogs and rabbits. The daily ingestion of glass fragments (3–12 mm.) in dogs for 2 months produced no injury to the gastrointestinal tract of these animals. Although foods and beverages should be kept free of glass and metal fragments, it is quite unlikely that their ingestion will cause injury to the gastrointestinal tract.

ENGINEERING RESEARCH

How to select woven wire cloth.

EVERHART, J. L. *Materials in Design Eng. 47*, 110–13 (Mar. 1958).

To meet the requirements of specific applications, which vary widely in exposure time corrosion, heat, vibration and mechanical load, a wide range of weaves, meshes, and sizes from several materials has been developed. The author explains the terminology of structural factors, and illustrates weave varieties with principal applications.

FOOD AND FOOD TECHNOLOGY

Antioxidants

An antagonistic effect with antioxidants for unsaturated fats.

OLCOTT, H. S. AND EINSET, E. (Dept. of Food Technol., Univ. of California, Berkeley). *J. Am. Oil Chemists' Soc. 35*, 159–60 (1958).

α- and γ-tocopherol act as pro-oxidants with marine oils contg. the antioxidant EMQ. The term "antagonism" is suggested for such phenomena. Antagonism was also demonstrable in purified unsatd. fatty ester acids and triglycerides. Nitrogenous inhibitors (EMQ, DPPD, ADA) are more affected by added tocopherols than are the phenolic antioxidants examd. (BHT, BHA, PG, NDGA).

Baking and Bakery Products

The fortification of bread with lysine. IV. The nutritive value of lysine-supplemented bread in reproduction and lactation studies with rats.

CULIK, R. AND ROSENBERG, H. R. (E. I. du Pont, Newark, Del.). *Food Technol. 12*, 169–74 (1958).

Flour supplemented with 0.25% L-lysine · HCl produced a bread which, when used as the sole source of dietary protein, resulted in normal or near normal reproduction and lactation of 5 generations of rats as compared to poor performance of animals fed com. bread.

Cereals and Grains

Lysine supplementation of a breakfast cereal and milk combination.

THIESSEN, R. AND REUSSNER, G. H. (General Foods Research Center, Tarrytown, N. Y.). *J. Agr. Food Chem. 6*, 368–73 (1958).

This investigation was made to det. whether a positive growth response would be obtained from the addn. of 0.5% DL-lysine hydrochloride to a wheat flakes breakfast cereal, with and without the milk used in a customary serving. A 4-week rat feeding test indicated that

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the lysine supplement gave a growth response when wheat flakes were fed without milk—no significant increases in growth or protein efficeincy were noted with milk.

Cocoa and Cocoa Products

On the storage of raw cocoa beans in silo compartments.

THEIMER, O. F. *Intern. Chocolate Rev. 13*, 162–7 (1958).

Special devices (spiral slides, cascades, zig-zag-slides, and tubes) are needed when filling and emptying silos in order to prevent free falls of the beans and breakage from pressure. Artificial aeration, distant reading thermometers, dust removal and the size and shape of the silos are also discussed.

Chocolate product and process therefor.

RUSOFF, I. I. Assignor to General Foods Corp. U. S. 2,835,585. May 20, 1958.

A method for extracting fermented unroasted cacao material whereby the flavor and aroma precursors are sepd. from the cacao material using an aq. extracting liquid. After evaporation the resulting semi-solid mass is roasted to develop the chocolate flavor and aroma.

Process of producing an artificial chocolate flavor and the resulting product.

RUSOFF, I. I. Assignor to General Foods Corp. U. S. 2,835,590. May 20, 1958.

An artificial chocolate flavor is produced by reacting a saccharide with a glycyl or alanyl peptide ranging in molecular complexity from di- to hexa-peptides. The mixt. is in a substantially anhydrous state before the end of the reaction. The reaction temp. is dependent upon the type of saccharide selected.

Coffee

Wet roasting of green coffee.

CHASE, F. A., PLAINS, M. AND LEE, S. Assignors to Home Products Corp. U. S. 2,833,653. May 6, 1958.

The process described constitutes an improvement in the manufacture of sol. coffee wherein the unroasted coffee is heated under pressure above 300° F. The comminuted unroasted coffee is suspended in water and subjected to continued heating until a sudden rise of pressure of the order of 75–150 lbs./in.^{2} occurs. The aq. ext. is then sepd. from the grounds.

Dehydration

Water-vapor transfer in the in-package desiccation of dehydrated foods.

HENDEL, C. E., LEGAULT, R. R., TALBURT, W. F. AND BURR, H. K. (U. S. Dept. of Agr., Albany, Calif.). *Food Manuf. 33*, 206 (1958).

An equation for estimating the rate of in-package desiccation for studying the effects of the individual package components on the rate of desiccation has been developed. Estimated and observed drying-time values are in reasonable agreement, indicating that the method can serve as a guide for design of in-package desiccation systems, particularly in detg. the relative effect of the various package components. Transfer coeffs. needed for use in this equation have been detd. for materials representative of each of the package components and are given.

Fats and Oils

The metabolism of triglycerides containing cis and trans octadecenoic fatty acids.

ALLEN, R. R., KIESS, A. A., JOHNSTON, P. V. AND KUMMEROW, F. A. (Univ. of Illinois, Urbana). *J. Am. Oil Chemists' Soc. 35*, 203–5 (1958).

Weanling rats were fed diets contg. triglycerides composed of both *cis* and *trans* fatty acids for 16 days. The animals were sacrificed, and the lipides were extd. quantitatively from the heart, liver, feces, and the rest of the carcass. Infrared analyses were carried out to det. the fate of the *trans* acids. *Trans* acids with the double bond either in the 8 or 9 position are metabolized efficiently by the rat organism.

Distance between emulsified oil globules upon coalescence.

VAN TEMPEL, M. (Unilever Research Lab., Neth.). *J. Colloid Sci. 13*, 125–33 (1958).

Flocculated oil globules in an emulsion are still sepd. by a water film having a thickness of at least 100 A. A high potential barrier of electrostatic origin prevents closer contact between the particle surfaces. Coalescence occurs immediately upon rupture of this water film. The thickness of the water film decreases with increasing electrolyte concn. The exptl. results suggest the presence of still other repulsive forces which become operative at distances between the interfaces smaller than about 125 A.

Fruits and Vegetables

Control of navel bitter in dehydrated juice products.

SWISHER, H. E. Assignor to Sunkist Growers, Inc. U. S. 2,834,687. May 13, 1958.

A process for producing nonbitter dehydrated navel orange juice which comprises extracting the juice from navel oranges, adjusting the pH to 5–7 to inhibit the development of bitterness, concentrating, dehydrating to a moisture content of less than 4% and adding citric acid sufficient to obtain a pH from 3.4 to 4.5 upon reconstitution with water.

Meat and Fish

Process for improving the color of animal material.

SAVICH, A. L. AND JANSEN, C. E. Assignors to Swift and Co. U. S. 2,830,707. April 15, 1958.

Process for improving the color of animal material having an oxygen carrying pigment. A bright red color is obtained upon the addn. of a compn. selected from the group consisting of propionic acid and its edible salts and esters together with ascorbic acid.

Starch

Radiochemical evidence for heterogeneity in wheat starch.

PERLIN, A. S. (Prairie Regional Lab., Saskatoon, Can.). *Can. J. Chem. 36*, 810–13 (1958).

Wheat starches labeled with carbon-14 have been fractionated by a novel leaching procedure to give amylose, amylopectin, and a highly-branched minor fraction designated "amylopectin C." Marked differences in the specific activity of the fractions are found. Subfractionation of amylopectin also gives products of varying specific activity. These findings provide radiochem. evidence for heterogeneity in wheat starch.

Taste Testing

Electron microscopic observations on the taste buds of the rabbit.

DE LORENZO, A. J. (Dept. of Anatomy, Washington Univ., School of Med., St. Louis, Mo.). *J. Biophys. Biochem. Cytol. 4*, 143–8 (1958).

An examn. of the fine structure of the taste buds in the rabbit was undertaken. The bud contains 2 types of cells, gustatory receptors and sustentacular cells. The receptors are characterized by a dark nucleus and densely granular cytoplasm. The subepithelial nerve plexuses comprise the fibers which innervate the gustatory receptors. The intragemmal fibers enter the taste bud between adjacent cells, and are ensheathed by the plasma membranes of the supporting cell until they synapse upon the gustatory cell. The synaptic terminals contain synaptic vesicles, which at this junction reside in the postsynaptic element. This observation is discussed with reference to synapses described elsewhere in the nervous system.

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Radiochemical Technology

Accumulation of dietary boron and strontium in young and adult albino rats.

FORBES R. M. AND MITCHELL, H. H. (Univ. of Illinois, Urbana). *Arch. Ind. Health 16*, 489–92 (1957).

Data are presented relative to accumulation of boron as boric acid and of strontium as strontium nitrate fed to young and to adult rats for periods of 4 and 8 weeks. In young rats the % of dietary boron retained was inversely proportional to its concn. in the diet, ranging from a retention of 0.49% to 0.17% as dietary concn. increased from 19 to 198 p.p.m. This trend was not noticeable in the adult rats. Strontium accumulation in the skeleton averaged 2.7% of that fed, a figure that was not obviously influenced by sex or age of the animal or by the concn. of strontium (30 to 1030 p.p.m.) in the diet.

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